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DETERMINATION AND EXTRACTION OF PECTIN FROM CITRUS AND OTHER FRUITS [1]

VICENTE RONGO AND SALUD L. QUIATSON

For the preparation of jellies some fruits are more suitable than others. It is believed that the difference is due to the pectin content of the fruit.

Fruits which might otherwise be discarded either because they are too ripe or because they are not suited for jelly making owing to the lack or insufficient content of pectin can be utilized by the addition of pectin extract. As early as 1750, jellies were prepared from apple and from currant juices in preference to other juices. It has long been a practice to reinforce fruit juices of poor jellying power with apple juice to produce a good jelly. To accomplish the same effect, it had been recommended that pectin solution be prepared from apple juice or from peels of citrus fruits. These pectin solutions do not change the natural flavor of the fruits to which they are added. Jellies formed with the added pectin are as good as those obtained from fruits of the best jellying quality.

Pectin is so widely distributed in nature that the raw materials for its manufacture are practically unlimited. Most of the manufactured pectin sold in the market is taken from apple by-products, citrus by-products, and other fruits. New uses of pectin other than for jelly making are fast being developed. Pectin is now used in meringue powders, cakes, cake icings, crushed fruits for soda fountains, mayonnaise, and other salad dressings. It is also used in tree sprays against pests and diseases, as an emulsifying agent in castor and mineral oil preparations, and as glue and mucilage. A very recent use of pectin is as blood agglutinant in the treatment of intestinal hemorrhages.

In the Philippines, fruits are seasonal. The price of fruits goes down when there is a comparatively large supply and the housewives can take advantage of this by making jellies, jams, and marmalades with the aid of extracted pectin.

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[1] Experiment Station contribution No. 1355. Prepared in the Department of Agricultural Chemistry under the direction of Associate Professor A. I. de Leon.

Review of literature

Bigelow, Gore, and Howard (1905) report that Chodnew in 1844 extracted pectin from pears and apples by boiling the crushed fruits in water, filtering the products, and precipitating the filtrate with alcohol. The same authors state that six hours boiling with water under a reflux condenser for successive periods of one hour each did not completely extract pectin from the apple pulp. They found that pectin showed a rotatory power of $(\alpha)D = + 71.2°$ to $78.7°$ with 1.851 per cent solution polarized at $3.8°$ to $4.2°$ in a Schmidt and Haensch polariscope in a 10 cm. tube.

Hunt (1918) found that pectin can be prepared by adding ammonium sulfate to the hot water extract of the fruit and heating to 70°C. The amount of pectin recovered is practically equivalent to that recovered by the alcohol precipitation method.

Magoon and Caldwall (1918) showed that pectin can be precipitated also by magnesium sulfate.

Wickmann (1922) reported that if pectin is precipitated as calcium pectate, the precipitate is not pure but a mixture of calcium pectate and calcium chloride. By boiling this precipitate with dilute hydrochloric acid, the calcium pectate is converted into pectic acid.

Norman (1928) worked on lemon juice and determined the pectin content by precipitation with 95 per cent ethyl alcohol method and by the calcium pectate method. The yield from the calcium pectate method was only 67.2 per cent of the yield from the precipitation method.

Pectin can be estimated by titration of the acidity developed on saponification of pectin under constant conditions as shown by Ahmann and Hooker (1925). They found that the amount of pectin found is proportional to the acidity developed.

It had been noted by Myers and Baker (1927) that the higher the viscosity of a pectin solution, the more sugar must be added to maintain constant the strength of the resulting jelly. In order to adjust the strength of the jellies to 30 cm. water pressure, he added 80 grams sugar to a pectin solution with a viscosity of 302, and 140 grams to the solution with a viscosity of 530.

In a study as to the best conditions essential in extraction Hardy (1925) found that the total quantity of pectin extracted appears to vary directly with the H-ion concentration and with the temperature.

Ahmann and Hooker (1925) state that von Fallenberg in 1918 studied the constitution of pectin and concluded that it is the methyl ester of pectic acid.

Sucharipa (1923) stated that there are three classes of pectic substances: namely, pectin, proto-pectin, and pectic acid. Free pectin, the only pectic substance soluble in water, is present in fruits and other soft parts of the plant both in the juice and in the cell. This has the highest jellying power in the entire pectin group.

In regard to the pectin content of Philippine fruits, Adriano (1932) found that red fruits of bignay [*Antidesma bunius* (Linn.) Spreng.] and ripe fruits of guava (*Psidium guajava* Linn.) contain high amounts of pectin.

Object of the present work

This work was undertaken to determine quantitatively the pectin content of citrus and some other fruits grown in the Philippines and to study some of the physical and chemical properties of the extracted pectin.

Time and place of the present work

This work was done between June, 1932, and February, 1933, and between January, 1937, and May, 1938. All analyses were performed in the laboratory of the Department of Agricultural Chemistry, College of Agriculture, Los Baños, Laguna.

MATERIALS AND METHODS

Materials

Only mature fruits were used. The names, both common and scientific, of most fruits used were obtained from E. D. Merrill (1923) "An Enumeration of Philippine Flowering Plants"; T. Tanaka (1932) "Philippine Rutaceae—Aurantioideae" (Revisio Aurantiacearum VII) and T. Tanaka (1937) "Further Revision of Rutaceae—Aurantioideae of India and Ceylon" (Revisio Aurantiacearum VIII).

Some of the citrus fruits were collected from the Tanauan Citrus Station of the Bureau of Plant Industry, Tanauan, Batangas, whose cooperation is hereby acknowledged. The rest of the citrus and the other fruits were obtained either from the Pomology Division of the College of Agriculture or from the stores in the vicinity of Los Baños. The following fruits were used.

1. Alsem, *Citrus webberii* Wester (resembles sour orange or culubot).
2. Balimbing, *Averrhoa carambola* Linn.
3. Bignay, *Antidesma bunius* (Linn.) Spreng.
4. Calamondin, *Citrus microcarpa* Bunge
5. Chico, *Achras zapota* Linn.

6. Chinese pummelo, *Citrus grandis* Osbeck.
7. Citron, *Citrus medica* Linn.
8. Duhat, *Eugenia cumini* (Linn.) Druce.
9. Guava, *Psidium guajava* Linn.
10. Hung lemon, *Citrus* sp.
11. Sweet orange (kajel), *Citrus sinensis* Osbeck
12. Karanda berry, *Carissa carandas* Linn.
13. King orange, *Citrus nobilis* Lour.
14. Ladu mandarin, *Citrus paratangerina* Hort.
15. Lanzones, *Lansium domesticum* Correa.
16. Macopa, *Eugenia javanica* Lam.
17. Tizon, *Citrus papillaris* Blanco.
18. Marsh seedless pummelo, *Citrus paradisi* Macf.
19. McCarty pummelo, *Citrus paradisi* Macf.
20. Batangas mandarin, *Citrus reticulata* Blanco
21. Panuban (similar to grape fruit), *Citrus panuban* (Wester) Hort.
22. Pink pummelo, *Citrus grandis* Osbeck.
23. Native pummelo (suha), *Citrus grandis* Osbeck.
24. Rough lemon, *Citrus jambhiri* Lush.
25. Saagkam mandarin, *Citrus reticulata* Blanco
26. Saigon pummelo, *Citrus grandis* Osbeck.
27. Santol, *Sandoricum koetjape* (Burm. f.) Merr.
28. Satsuma, *Citrus unshiu* Marc.
29. Siamese pummelo, *Citrus grandis* Osbeck.
30. Sour orange, *Citrus aurantium* Linn.
31. Star apple, *Chrysophyllum cainito* Linn.
32. Szinkom, *Citrus deliciosa* Ten.
33. Tamarind, *Tamarindus indica* Linn.
34. Tangelo, Citrus hybrid (*C. paradisi* Macf., × *C. reticulata* Blanco) (similar to orange).
35. Triumph pummelo, *Citrus paradisi* Macf.

Methods of analysis

Preparation of samples. (1) *Weight.* The fruits were selected at random. Then the weights of at least three when specimens were rare to fifteen when fruits were abundant were determined.

(2) *Determination of portion of fruit used.* In the case of citrus fruits the albedo portion (white portion of the peel of the citrus fruit) was used. This was determined by weighing the whole fruit and removing the outer pulp. From the weight of the whole fruit and the weight of the albedo, the percentage albedo was calculated.

In general, the seeds of fruits were first removed and the remaining portion as well as the albedo passed through a meat grinder. In the case of balimbing, the whole fruit was used.

Analysis. (1) *Moisture.* Approximately two to five grams of the sample were weighed carefully in tared porcelain crucibles and dried to constant weight in a Freas constant temperature electric oven kept at 100° to 105°C. The difference in weight before and after drying was taken as the amount of moisture in the sample.

(2) *Extraction of the pectin.* About 35-500 grams of the prepared ground sample were placed in a big porcelain dish and five times that weight of 0.15 per cent HCl were added. The solution was boiled for 30 minutes at 100°C. and stirred with a glass rod. It was filtered through cheese cloth and pressed as dry as possible. The filtrate was placed in a 1-liter volumetric flask and diluted to the mark. Aliquots of from 100 to 300 ml. were measured, placed in 800-ml. beakers, and evaporated to about half their volumes. These were cooled immediately to about 30°C., and twice their volume of 95 per cent alcohol was added slowly with constant stirring until a precipitate was formed. This solution was set aside for two to six hours, allowed to settle, and filtered through filter paper. The precipitate was washed twice with 95 per cent alcohol.

The entire precipitate was transferred into the original beaker and dissolved with hot water to about 300 ml. This solution was evaporated to about 200 ml. and immediately cooled to 30°C., then 400 ml. of 95 per cent alcohol was added slowly with constant stirring until a precipitate was formed. The solution was set aside for two to six hours.

The solution was filtered and the precipitate washed several times with 95 per cent ethyl alcohol, then with ether. The precipitate was collected in a tared 150-ml. beaker, dried at 60°C., and weighed. From the weight of the dried precipitate the percentage of pectin was calculated.

(3) *Physical and chemical properties of the extracted pectin.* (*a*) *Moisture.* The moisture content of the extracted pectin was determined by weighing about one gram of the pectin in tared porcelain crucibles and drying to constant weight in a Freas constant temperature electric oven kept at 100° to 103°C. The difference in weight before and after drying was considered the amount of moisture in the sample.

(*b*) *Ash.* The residue from the determination of moisture was carefully charred and heated at low red heat in a muffle furnace until

a white or grayish white residue free from carbon particles was obtained. This was weighed until a constant weight was obtained and the percentage of ash calculated.

(*c*) *pH determination.* Samples of the extracted pectin weighing 0.5 gram were dissolved in hot water, then made up to 100 ml. The pH of the different pectin samples was determined by the use of a Leads and Northrup potentiometer with a quinhydrone electrode.

(*d*) *Total acidity.* Samples of the extracted pectin weighing about 0.5 gram were dissolved in hot water, then cooled, and made up to 100 ml. Aliquots of 25 ml. were pipetted off and titrated with standard NaOH solution, phenolphthalein being used as indicator. The results were reported in milliliters of 0.1N NaOH per gram of the sample.

(*e*) *Viscosity.* Samples were prepared as above and the viscosity was measured at 28.5°C.; an Ostwald viscosimeter was used.

(*f*) *Specific rotation.* Samples of 0.1 to 0.2 gram of the extracted pectin were dissolved with hot water, diluted to exactly 100 ml., clarified with dry basic lead acetate, and filtered. The average rotation was taken and the specific rotation determined.

(*g*) *Pectic acid.* Samples of pectin weighing 0.5 to 1.6 grams were weighed, dissolved in hot water, and made up to 100 ml. Aliquots of 50 ml. were taken and were evaporated to about 25 ml. Addition of alcohol precipitated the pectin, which was filtered, dissolved in hot water, saponified with 10 per cent sodium hydroxide, and boiled for five minutes after addition of hydrochloric acid. The precipitate of pectic acid was washed with water, transferred into the beaker originally used for the precipitation, adjusted to 40 ml. in volume, and cooled to 25°C. The pectic acid obtained was again dissolved, saponified, and reprecipitated; and the pure pectic acid obtained was washed into an aluminum dish and dried on a steam bath and finally in the oven to constant weight. The residue was weighed, ignited, and weighed again. The loss in weight represents the pectic acid value.

(*h*) *Purity of the extracted pectin.* The Ahmann and Hooker (1925) method of estimating pectin was used. Samples weighing 0.45 gram were dissolved in hot water and made up to 100 ml. Fifty milliliter aliquots were pipetted into 250-ml. volumetric flasks, 50 ml. of standard sodium hydroxide added, and the whole diluted to the mark. The contents were next transferred into Erlenmeyer flasks, sealed, and allowed to stand for 12 hours at 55°C. in the oven. After hydrolysis, aliquots were taken and titrated with standard hy-

drochloric acid. From the number of milliliters of alkali used by the pectin solution, the amount of pectin was calculated.

(*i*) *Preparation of the jelly.* Samples of 0.5 gram of the extracted pectin were dissolved in hot water in tared 400-ml. beakers. To this solution were added 50 grams sugar and variable amounts (5 ml., 10 ml., and 15 ml.) of 0.1N citric acid. The beaker was weighed often in an attempt to obtain a jelly weighing 65 grams. The jelly formed was poured into a 50-ml. beaker provided with a watch glass and placed at once in a desiccator.

The jelly strength was determined after 24 hours by a water pressure apparatus similar to that devised by Tarr (1926) for the determination of jelly strength.

DISCUSSION OF RESULTS

The pectin content of the fruits was obtained by precipitation with alcohol.

Table 1 shows the albedo content, the moisture content, and the average yield of pectin extracted from different varieties of fruits. The calculations are based on the albedo in the case of citrus, and on the weight of the edible portion of the fruit in the case of the other fruits. Hung lemon gave the highest pectin content, 30.03 per cent, and duhat the lowest, 1.55 per cent. Calamondin gave 14.88 per cent, while Adriano (1932) reported 12.29. The difference may be attributed to the fact that in the present work an acid medium was used in the extraction, while Adriano used plain water. A study of the figures shows that citrus fruits give higher yields of pectin than the other fruits studied. Star apple and balimbing did not give any appreciable amount of pectin and are not included in the tables here presented. The moisture content varies from Triumph pummelo, 85.55 per cent, to tangelo, 68.33 per cent.

Table 2 shows the ash and moisture content, viscosity, total acidity, and pH value of the extracted pectin. The highest ash content was obtained from the pectin extracted from rough lemon, 6.45 per cent. This result is very much lower than that found in lemon juice by Norman (1928), who reported 11.88 per cent ash, even after five extractions with alcohol. The other fruits gave lower percentages ranging from 6.05 to 1.03 per cent. Myers and Baker (1929) found that the extraction of pectin in the presence of acid results in lower ash content than when the extractions are conducted in a neutral medium. They explained that this was due to the effect of the hydrogen ion on the salts of the fruit acids during the extraction

from pectic materials. They pointed out that the metallic ions present in the carboxyl group of the pectin molecules were replaced by the hydrogen ions, rendering the salts soluble and thus helping eliminate the metallic elements from the precipitate. The above explains why the ash content of pectin found in the present work is very much lower than that found by Norman.

As shown in table 2 the viscosity of 0.5 per cent pectin solution varied from 1.058 to 2.234. According to Myers and Baker (1927), there is a direct relation between viscosity and strength of the resulting jelly.

The pH value of the 0.5 per cent solution is more or less constant, being from 2.3 in the case of lanzones to 3.4 in tamarind. The pectin with comparatively high pH value was found to have poorer jellying quality. Tarr (1926) suggested that the hydrogen ion concentration might be used as a means of controlling jelly formation and uniformity of the product. They found that hydrogen ion concentration of poor jelly fruit juice was high in pH value, less than pH 3.4.

Table 3 shows the percentage of pectic acid from the extracted pectin. The highest yield of pectic acid obtained was 74.26 per cent from Ladu mandarin. This result approaches the value, 76.8 per cent, found by Myers and Baker (1929) from pectin extracted from albedo of lemon. Poore (1926) reported 63.86, 62.76, and 54.8 per cent pectic acid from apple, lemon, and orange, respectively. The lowest pectic acid in the present work was 16.88 per cent from tamarind.

Correlating the pectic acid content with the jelly strength of jellies as indicated in table 6, it is observed that the quantity of pectic acid is an indication of the jellying power of the extracted pectin. Pectin from Ladu mandarin, rough lemon, citron, and Hung lemon produced excellent jellies and all contained high pectic acid, Ladu mandarin 74.26, rough lemon 72.03, Citron 71.09, and Hung lemon 73.22 per cent. Pink pummelo with pectic acid content of 49.95 per cent did not form any jelly. Similarly, those of lower pectic acid content failed to yield satisfactory jellies. Marsh seedless pummelo yielded 58.31 per cent and Batangas mandarin 55.63 per cent, yet these fruits have poor jellying power.

The purity of the extracted pectin was determined by the Ahmann and Hooker titration method and reported in table 4. The values obtained vary from 97.44 per cent for Szinkom to 82.50 per cent for Karanda berry.

Table 5 shows the specific rotation of the extracted pectin. The highest specific rotation was obtained from Karanda berry and the lowest from bignay. The specific rotation ranges from 110.00 to 240.00. These results are comparable to those found by Andrlick (1895) who reported pectin of the specific rotatory power of 214.4° to 220°. According to Bigelow, Gore, and Howard (1905) Javillier in 1899, using the methods of Bourquollot and Herissey, obtained a dextro-rotatory pectin with the rotation of $(\alpha)D = 188.2°$.

Table 6 shows a comparison of the jelly strength of jellies made from the extracted pectin. Pectin from the different varieties produced jellies of different strengths.

Pectin from macopa and guava gave the best jelly with strength of 148.00 and 79 cm. water respectively, 15 ml. of 0.1N citric acid being used in both cases. It was observed that in some cases jelly strength tended to increase as the volume of the citric acid was increased. Native pummelo, alsem, chico, duhat, Satsuma, and guava are examples of this type. With most of the citrus fruits, such as Ladu mandarin, Tangelo, and Marsh seedless pummelo, the jelly strength decreased as the volume of the citric acid was increased.

Star apple and balimbing did not yield any appreciable amount of pectin and have not been included in the tables here presented.

SUMMARY AND CONCLUSIONS

1. The yield of pectin from thirty-three fruits was determined. The yield ranged from 30.03 per cent in Hung lemon to 1.55 per cent in duhat.

2. The pectic acid content of the extracted pectin varied in the different fruits from 74.26 per cent in Ladu mandarind to 16.88 per cent in tamarind. The amount of pectic acid seemed to show direct relations to the jelly strength of the pectin.

3. The purity of the extracted pectins, as determined by the Ahmann and Hooker titration method, ranged from 97.44 per cent in Szinkom to 82.50 per cent in Karanda berry.

4. The extracted pectins were dextro-rotatory with specific rotation ranging from 240.0° for Karanda berry to 110.0° for bignay.

5. The moisture and ash content, total acidity, viscosity, and pH value of the extracted pectins were determined. Santol gave the highest moisture content, 8.25 per cent, while sour orange gave the lowest, 1.21 per cent. The ash content varied from 6.45 per cent in rough lemon to 1.03 per cent in tamarind. Total acidity ranged from

32.80 ml. of 0.1N NaOH per gram pectin in bignay to 3.09 in Hung lemon. The viscosity of 0.5 per cent pectin solution varied from 2.060 in Hung lemon to 1.078 in Marsh seedless pummelo. The pH value was from 3.4 of tamarind to 2.3 of lanzones.

6. The jelly strength of the pectin from the different fruits was compared and was found to vary directly with viscosity and inversely with pH value. Those pectin solutions having 2.6 to 2.7 pH value gave the best jellies while those having 2.9 to 3.4 gave the poorest jellies.

The results in these experiments point to the possibility of making jellies of excellent quality with pectin from the different fruits, provided that the proper amounts of acid and sugar are added.

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TABLE 1

Percentage yield of pectin by precipitation with 95 per cent ethyl alcohol

NAME OF FRUIT	ALBEDO CONTENT	MOISTURE CONTENT	PECTIN YIELD
	per cent	*per cent*	*per cent*
Alsem	22.30	71.70	7.88
Bignay	—	83.12	3.19
Calamondin	11.57	70.01	14.88
Chico	—	73.06	1.97
Chinese pummelo	46.67	81.43	24.66
Citron	22.61	80.25	17.36
Duhat	—	85.35	1.55
Guava	—	75.25	5.45
Hung lemon	11.60	75.09	30.03
Kajel (sweet orange)	16.47	78.36	25.92
Karanda berry	—	87.39	7.21
King orange	28.94	78.15	13.84
Ladu mandarin	13.53	80.68	21.48
Lanzones	—	84.65	2.23
Macopa	—	92.37	8.73
Tizon	11.20	73.58	25.24
Marsh seedless pummelo	16.42	81.65	16.40
McCarty pummelo	20.42	73.53	19.64
Batangas mandarin	12.44	76.58	14.73
Panuban	18.27	76.18	18.43
Pink pummelo	48.84	80.77	17.73
Native pummelo	59.76	78.23	23.33
Rough lemon	16.81	76.63	10.86
Saagkam mandarin	21.61	79.83	10.31
Saigon pummelo	39.27	83.75	24.98
Santol	—	85.59	6.47
Satsuma	15.68	79.69	23.58
Siamese pummelo	18.28	77.77	16.77
Sour orange	21.69	70.83	18.61
Szinkom (mandarin)	13.07	74.24	18.21
Tamarind	—	72.37	10.43
Tangelo	9.06	68.33	21.50
Triumph pummelo	33.21	85.55	21.93

TABLE 2

Data for moisture, ash, total acidity, viscosity, and pH value of extracted pectin

PECTIN EXTRACTED FROM	MOISTURE CONTENT	ASH CONTENT	VOL. OF 0.1N NaOH REQUIRED PER GRAM PECTIN	VISCOSITY OF 0.5% PECTIN SOLUTION	pH OF 0.5% PECTIN SOLUTION
	per cent	*per cent*	*ml.*		
Alsem	5.86	2.18	10.60	1.522	2.8
Bignay	2.03	5.97	32.80	1.083	3.2
Calamondin	1.65	5.68	9.18	1.268	3.0
Chico	4.93	1.46	21.20	1.203	2.3
Chinese pummelo	1.80	4.15	7.89	1.613	2.8
Citron	1.34	3.60	4.17	1.706	2.7
Duhat	8.21	4.73	22.80	1.220	2.6
Guava	2.46	2.11	19.20	1.500	2.6
Hung lemon	3.12	5.90	3.09	2.060	2.7
Kajel (sweet orange)	1.50	5.44	6.64	1.977	2.7
Karanda berry	8.16	1.77	23.20	1.125	2.5
King orange	2.98	4.53	8.41	1.891	2.6
Ladu mandarin	1.85	1.65	7.69	2.234	2.6
Lanzones	6.65	3.72	31.00	1.152	2.3
Macopa	6.00	1.34	25.20	1.286	2.7
Tizon	1.80	5.12	6.82	1.697	2.7
Marsh seedless pummelo	4.32	2.33	7.58	1.078	2.9
McCarty pummelo	1.82	5.15	7.81	1.822	2.7
Batangas mandarin	1.47	6.05	6.51	1.331	2.9
Panuban	1.52	4.97	8.00	1.654	2.8
Pink pummelo	2.18	5.82	9.48	1.058	3.0
Native pummelo	4.58	4.51	9.49	1.603	2.8
Rough lemon	1.96	6.45	8.60	2.028	2.7
Saagkam mandarin	2.26	4.89	7.71	1.485	2.8
Saigon pummelo	2.08	5.59	7.31	1.450	2.8
Santol	8.25	2.09	17.20	1.951	2.9
Satsuma	5.10	4.49	7.50	1.447	2.8
Siamese pummelo	2.15	4.44	7.68	1.646	2.8
Sour orange	1.21	3.18	3.45	1.966	2.7
Szinkom (mandarin)	4.62	3.87	9.80	1.920	2.7
Tamarind	6.94	1.03	11.40	1.241	3.4
Tangelo	4.55	2.11	5.80	1.113	2.9
Triumph pummelo	3.51	4.30	5.72	1.688	2.8

TABLE 3

The percentage pectic acid from the extracted pectin

PECTIN EXTRACTED FROM	WEIGHT OF SAMPLE	WEIGHT OF PECTIC ACID	YIELD OF PECTIC ACID
	gram	*gram*	*per cent*
Alsem	0.5001	0.3213	64.25
Bignay	0.6721	0.2670	39.73
Calamondin	0.2966	0.1695	57.25
Chico	0.2946	0.0863	29.29
Chinese pummelo	0.5567	0.3405	60.09
Citron	0.4916	0.3475	71.09
Duhat	0.1856	0.0780	42.03
Guava	0.7892	0.4946	62.67
Hung lemon	0.5158	0.3740	73.22
Kajel (sweet orange)	0.2566	0.1698	66.30
Karanda berry	0.3420	0.1903	55.64
King orange	0.6367	0.3958	63.22
Ladu mandarin	0.6608	0.5320	74.26
Lanzones	0.2243	0.0996	44.42
Macopa	0.2683	0.1655	61.68
Tizon	0.1929	0.1260	65.39
Marsh seedless pummelo	0.5910	0.2447	58.31
McCarty pummelo	0.6807	0.4657	68.42
Batangas mandarin	0.4607	0.2568	55.63
Panuban	0.5106	0.3182	62.73
Pink pummelo	0.5656	0.2830	49.95
Native pummelo	0.6673	0.4217	63.19
Rough lemon	0.4794	0.3093	72.03
Saagkam mandarin	0.3673	0.2212	60.22
Saigon pummelo	0.6009	0.3580	59.60
Santol	0.7127	0.4994	70.07
Satsuma orange	0.4757	0.2871	60.35
Siamese pummelo	0.7609	0.4776	62.80
Sour orange	0.8121	0.5089	63.66
Szinkom (mandarin)	0.5681	0.3660	64.99
Tamarind	0.6298	0.1063	16.88
Tangelo	0.5016	0.2950	57.92
Triumph pummelo	0.6186	0.4064	66.40

TABLE 4

Purity of extracted pectin by Ahmann and Hooker titration method

PECTIN EXTRACTED FROM	WEIGHT OF SAMPLE	WEIGHT OF PECTIN BY TITRATION METHOD	PURITY OF PECTIN
	gram	*gram*	*per cent*
Alsem	0.0225	0.02116	93.95
Bignay	0.4970	0.44188	88.91
Calamondin	0.0225	0.02061	91.59
Chico	0.4240	0.41129	97.00
Chinese pummelo	0.0225	0.02014	89.63
Citron	0.0225	0.02092	92.98
Duhat	0.4060	0.36540	90.00
Guava	0.4580	0.43152	94.22
Hung lemon	0.0225	0.02052	91.22
Kajel (sweet orange)	0.0225	0.02159	95.96
Karanda berry	0.4120	0.33990	82.50
King orange	0.0225	0.02138	95.04
Ladu mandarin	0.0225	0.01986	88.26
Lanzones	0.4915	0.48947	99.59
Macopa	0.4683	0.41639	88.92
Tizon	0.0225	0.02128	94.64
Marsh seedless pummelo	0.0225	0.02046	90.92
McCarty pummelo	0.0225	0.02046	90.92
Batangas mandarin	0.0225	0.02079	92.42
Panuban	0.0225	0.02059	91.54
Pink pummelo	0.0225	0.02062	90.06
Native pummelo	0.0225	0.02092	92.98
Rough lemon	0.0225	0.02042	90.98
Saagkam mandarin	0.0225	0.02064	91.75
Saigon pummelo	0.4717	0.46738	99.08
Santol	0.0225	0.02016	89.57
Satsuma orange	0.0225	0.01980	87.77
Siamese pummelo	0.0225	0.02021	89.82
Sour orange	0.0225	0.02056	91.39
Szinkom (mandarin)	0.0225	0.02194	97.44
Tamarind	0.4104	0.56540	89.04
Tangelo	0.0225	0.02046	90.92
Triumph pummelo	0.0225	0.02048	91.22

TABLE 5

The specific rotation of extracted pectin

PECTIN EXTRACTED FROM	WEIGHT OF PECTIN PER 100 ml.	AVERAGE ANGULAR ROTATION	SPECIFIC ROTATION
	gram	*degrees*	*degrees*
Alsem	0.1722	+0.24	138.89
Bignay	0.1000	+0.11	110.00
Calamondin	0.1988	+0.41	206.14
Chico	0.1319	+0.22	166.79
Chinese pummelo	0.1488	+0.26	174.72
Citron	0.1954	+0.36	189.36
Duhat	0.1199	+0.15	125.10
Guava	0.1194	+0.17	142.37
Hung lemon	0.1718	+0.27	163.56
Kajel (sweet orange)	0.1942	+0.42	215.75
Karanda berry	0.1000	+0.24	240.00
King orange	0.1738	+0.20	161.10
Ladu mandarin	0.1832	+0.31	169.16
Lanzones	0.1293	+0.18	139.21
Macopa	0.1037	+0.23	221.79
Tizon	0.1600	+0.28	150.00
Marsh seedless pummelo	0.1732	+0.26	150.11
McCarty pummelo	0.1536	+0.26	169.26
Batangas mandarin	0.1728	+0.28	162.36
Panuban	0.1478	+0.23	162.45
Pink pummelo	0.1972	+0.45	228.19
Native pummelo	0.1900	+0.29	152.63
Rough lemon	0.1888	+0.31	164.18
Saagkam mandarin	0.1974	+0.30	166.61
Saigon pummelo	0.1348	+0.23	170.62
Santol	0.1536	+0.23	149.73
Satsuma orange	0.1228	+0.22	179.23
Siamese pummelo	0.1898	+0.31	168.58
Sour orange	0.1808	+0.29	150.88
Szinkom (mandarin)	0.1928	+0.34	173.27
Tamarind	0.1000	+0.14	140.00
Tangelo	0.1928	+0.31	156.92
Triumph pummelo	0.1632	+0.25	153.24

TABLE 6

The comparison of jelly strength of the jellies made from the extracted pectin

PECTIN EXTRACTED FROM	WEIGHT OF SAMPLE	WEIGHT OF SUGAR	VOL. OF 0.12N. CITRIC ACID	WEIGHT OF JELLY	JELLY STRENGTH PRESSURE IN CM. H_2O	PHYSICAL CHARACTER
	gram	*grams*	*ml.*	*grams*		
Alsem	0.5	50	5	65	15.40	Firm jelly
	0.5	50	10	65	20.85	Very firm jelly
	0.5	50	15	65	27.30	Very firm jelly
Bignay	0.5	50	5	65	[a]	Syrup
	0.5	50	10	65	[a]	Syrup
	0.5	50	15	65	[a]	Syrup
Calamondin	0.5	50	5	65	[a]	Thick syrup
	0.5	50	10	65	3.55	Soft jelly
	0.5	50	15	65	4.30	Soft jelly
Chico	0.5	50	5	65	18.00	Very soft jelly
	0.5	50	10	65	22.00	Soft jelly
	0.5	50	15	65	60.00	Weak jelly
Chinese pummelo	0.5	50	5	65	18.65	Firm jelly
	0.5	50	10	65	16.05	Firm jelly
	0.5	50	15	65	14.90	Firm jelly
Citron	0.5	50	5	65	40.85	Excellent jelly
	0.5	50	10	65	29.65	Very firm jelly
	0.5	50	15	65	25.65	Very firm jelly
Duhat	0.5	50	5	65	7.00	Thick syrup
	0.5	50	10	65	10.00	Thick syrup
	0.5	50	15	65	16.00	Very soft jelly
Guava	0.5	50	5	65	67.00	Firm jelly
	0.5	50	10	65	70.00	Firm jelly
	0.5	50	15	65	77.00	Excellent jelly
Hung lemon	0.5	50	5	65	45.55	Excellent jelly
	0.5	50	10	65	33.65	Very firm jelly
	0.5	50	15	65	29.30	Very firm jelly
Kajel	0.5	50	5	65	31.20	Very firm jelly
	0.5	50	10	65	28.95	Very firm jelly
	0.5	50	15	65	26.18	Very firm jelly
Karanda berry	0.5	50	5	65	[b]	Crystal formed
	0.5	50	10	65	143.00	Excellent jelly
	0.5	50	15	65	133.00	Excellent jelly

[a] The jelly strength was not measured.

[b] The jelly was very hard.

TABLE 6 (continued)

PECTIN EXTRACTED FROM	WEIGHT OF SAMPLE	WEIGHT OF SUGAR	VOL. OF 0.12N. CITRIC ACID	WEIGHT OF JELLY	JELLY STRENGTH PRESSURE IN CM. H_2O	PHYSICAL CHARACTER
	gram	*grams*	*ml.*	*grams*		
King orange	0.5	50	5	65	38.65	Very firm jelly
	0.5	50	10	65	35.40	Very firm jelly
	0.5	50	15	65	31.30	Very firm jelly
Ladu mandarin	0.5	50	5	65	50.55	Excellent jelly
	0.5	50	10	65	37.70	Very firm jelly
	0.5	50	15	65	31.00	Very firm jelly
Lanzones	0.5	50	5	65	12.00	Very soft jelly
	0.5	50	10	65	18.00	Very soft jelly
	0.5	50	15	65	51.00	Weak jelly
Macopa	0.5	50	5	65	28.00	Soft jelly
	0.5	50	10	65	76.00	Excellent jelly
	0.5	50	15	65	148.00	Excellent jelly
Tizon	0.5	50	5	65	38.55	Very firm jelly
	0.5	50	10	65	23.75	Very firm jelly
	0.5	50	15	65	20.70	Firm jelly
Marsh Seedless pummelo	0.5	50	5	65	5.15	Soft jelly
	0.5	50	10	65	4.20	Soft jelly
	0.5	50	15	65	1.35	Very soft jelly
McCarty pummelo	0.5	50	5	65	33.55	Very firm jelly
	0.5	50	10	65	19.80	Firm jelly
	0.5	50	15	65	15.45	Firm jelly
Batangas mandarin	0.5	50	5	65	5.30	Soft jelly
	0.5	50	10	65	3.75	Very soft jelly
	0.5	50	15	65	1.30	Very weak jelly
Panuban	0.5	50	5	65	15.80	Firm jelly
	0.5	50	10	65	21.20	Very firm jelly
	0.5	50	15	65	24.55	Very firm jelly
Pink pummelo	0.5	50	5	65	[a]	Thick syrup
	0.5	50	10	65	[a]	Thick syrup
	0.5	50	15	65	[a]	Thick syrup
Native pummelo	0.5	50	5	65	18.70	Firm jelly
	0.5	50	10	65	23.85	Very firm jelly
	0.5	50	15	65	26.45	Very firm jelly

[a] The jelly strength was not measured.

TABLE 6 (continued)

PECTIN EXTRACTED FROM	WEIGHT OF SAMPLE	WEIGHT OF SUGAR	VOL. OF 0.12N. CITRIC ACID	WEIGHT OF JELLY	JELLY STRENGTH PRESSURE IN CM. H_2O	PHYSICAL CHARACTER
	gram	*grams*	*ml.*	*grams*		
Rough lemon	0.5	50	5	65	26.75	Very firm jelly
	0.5	50	10	65	30.55	Very firm jelly
	0.5	50	15	65	41.20	Excellent jelly
Saagkam mandarin	0.5	50	5	65	9.35	Soft jelly
	0.5	50	10	65	14.70	Firm jelly
	0.5	50	15	65	19.70	Firm jelly
Saigon pummelo	0.5	50	5	65	7.10	Soft jelly
	0.5	50	10	65	5.40	Soft jelly
	0.5	50	15	65	[a]	Thick syrup
Santol	0.5	50	5	65	95.00	Excellent jelly
	0.5	50	10	65	87.00	Excellent jelly
	0.5	50	15	65	80.00	Excellent jelly
Satsuma orange	0.5	50	5	65	8.30	Soft jelly
	0.5	50	10	65	13.50	Firm jelly
	0.5	50	15	65	17.40	Firm jelly
Siamese pummelo	0.5	50	5	65	25.55	Very firm jelly
	0.5	50	10	65	27.65	Very firm jelly
	0.5	50	15	65	17.35	Very firm jelly
Sour orange	0.5	50	5	65	27.75	Very firm jelly
	0.5	50	10	65	20.50	Firm jelly
	0.5	50	15	65	18.20	Firm jelly
Szinkom mandarin	0.5	50	5	65	31.35	Very firm jelly
	0.5	50	10	65	38.65	Very firm jelly
	0.5	50	15	65	40.20	Excellent jelly
Tamarind	0.5	50	5	65	[a]	Syrup
	0.5	50	10	65	10.00	Very soft jelly
	0.5	50	15	65	12.00	Very soft jelly
Tangelo	0.5	50	5	65	4.05	Soft jelly
	0.5	50	10	65	3.20	Soft jelly
	0.5	50	15	65	1.80	Very weak jelly
Triumph pummelo	0.5	50	5	65	27.90	Very firm jelly
	0.5	50	10	65	21.50	Firm jelly
	0.5	50	15	65	16.30	Firm jelly

[a] The jelly strength was not measured.
[b] The jelly was very hard.

THE COMPARATIVE EFFECTS OF SOYBEAN AND PEANUT PLANTED WITH SUGAR CANE AND AMMONIUM SULFATE FERTILIZER UPON THE YIELD OF SUGAR CANE[1]

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A common practice in the culture of sugar cane is to supply the plant food materials lacking in the soil by commercial fertilizers. In some countries legumes such as mungo (*Phaseolus mungo* Roxb.), peanut (*Arachis hypogaea* Rac.), and soybean [*Glycine max* (Linn.) Merr.] have been used as intercrops to enrich the soil. Besides enriching the soil, the pods and seeds of legumes are said to be sources of cash for the farmers. Also, the legumes check some of the weeds, and thus save expenses in weeding. Although the intercropping with legumes requires extra labor, the income from the pods alone may more than pay for the cost of producing the main crop.

In the Philippines ammonium sulfate is the most common fertilizer for sugar cane. Since it is expensive, and legumes are known to enrich the soil with nitrogen, it should be of interest to know the comparative effects upon the yield of sugar cane of leguminous crops planted with the cane and in a soil to which a commercial fertilizer has been applied.

Very little work has been done on intercropping sugar cane with legumes. De Sornay (1916) in Mauritius found that legumes used in mixed cultivation with sugar cane prevented the growth of weeds and retained the soluble salts which would have been washed away by rain. A trailing variety of peanut was used. This author also suggested soybean as an intercrop because "it does not interfere in any way with the small canes; the soybean may be used on a mixed cultivation and may even be sown in two rows in interspaces of canes." He stated further: "we can only urge the sugar cane grower to make use of spaces between canes to cultivate peanut. This will not only furnish him with remarkable green manures but also enrich his soil, and thus be a source of real profit."

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[1] The data were obtained in part from an experiment conducted by the senior author and in part from the material presented as a thesis by the junior author for graduation, 1938, with the degree of Bachelor of Science in Agriculture, University of the Philippines; Experiment Station contribution No. 1356. Read before the Los Baños Biological Club, March 14, 1940.

Pritchett (1923) suggested the planting of legumes such as cowpeas and mungo between canes, as these have a restrictive habit of growth and thereby save the expense of plowing the "beaten down" soil after a heavy rain.

Earle (1928) stated that if the cultivated middles in sugar cane were planted to legumes at the beginning of the rainy season, they might keep down weeds and save expensive cultivation, and at the same time add nitrogen and humus to the soil. He suggested that only low growing legumes should be used for the purpose.

In the College of Agriculture at Los Baños, Valdez (1933) recommended soybean and peanut for intercroping with sugar cane ratoon crop, as he found that they increased the yield of the principal crop and saved two cultivations, one off-barring and one hilling-up.

From the work of these investigators, intercropping sugar cane with legumes appears to give beneficial results. In the College of Agriculture, however, Capili [2] found that the cane intercropped with legumes was stunted and gave lower yields of cane and sugar than the control. He also found that ammonium sulfate fertilizer gave significantly higher yields of cane and sugar than the control.

The objects of this work were: (*a*) to determine the comparative effects upon the production of cane and sugar of legumes planted in the row with sugar cane and with ammonium sulfate applied, and (*b*) to determine the quantity and value of the harvested legumes.

In this work two experiments were made. The first was conducted from October, 1935 to February, 1937, and the second from September, 1936 to February, 1938. Both cultures were in the Experiment Station field of the College of Agriculture.

MATERIALS AND METHODS

Sugar cane field and planting materials used. In the first experiment a sugar cane field with an area of 6,720 sq. m. was used. The soil is clay loam. Seed pieces of POJ 2878 were used. In the second experiment the field had an area of 7,404 sq. m. The soil is also clay loam. Cut-back seed pieces of sugar cane of the variety P.S.A. 14 were used.

Legumes used. The legumes used were obtained from the Annual Farm Crops Division of the Agronomy Department. They were soybean of the Ami variety and peanut of the Spanish Red and Valencia varieties.

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[2] CAPILI, ALFONSO A. A preliminary study of the comparative effects of leguminous crops planted with sugar cane and ammonium sulfate upon the yields of cane and sugar per hectare. (Thesis presented for graduation with the degree of Bachelor of Science in Agriculture. 1936. Unpublished.)

Fertilizer used. The ammonium sulfate fertilizer used contained 20.6 per cent available nitrogen.

Preparation of the land and laying out of the plots. In both experiments the field was plowed four times and harrowed after each plowing with a native harrow.

The field was divided into four lots, each of which was subdivided into five plots. These were arranged alternately to minimize as much as possible errors resulting from variability of soil fertility. In lot I, which was used as the control, the canes were not treated; in II, they were intercropped with peanut; in III, with soybean; and in IV, they were fertilized with ammonium sulfate. After the last harrowing, furrows were laid one meter apart immediately before planting.

Preparation of seed pieces. The seed pieces used in the first experiment were taken from recently harvested canes of POJ 2878. They were soaked in fresh running water for about thirty-six hours before planting. In the second experiment, cut-back seed pieces were prepared from immature canes about eight months old. The stalks were cut close to the ground and then cut into pieces varying in length from 25 to 35 centimeters, each containing three or more buds.

Planting seed pieces and legumes. The seed pieces were planted in rows one meter apart and 50 centimeters in the row. Just before they were covered, two to three peanut seeds were placed between the sugar cane hills in the plots intercropped with peanut, and two or three soybean seeds were placed between sugar cane hills in the plot intercropped with soybean. The sugar cane seed pieces and the peanut and soybean seeds were covered at the same time.

Application of commercial fertilizer. Before the seed pieces were covered, 15 grams of ammonium sulfate fertilizer were placed around each seed piece and later covered. At this rate of application about three hundred kilograms of the fertilizer were applied per hectare.

Care of culture. All the cultures were given the same care throughout the growing season. Alternate hilling-up and off-barring were done until the final cultivation, or closing-in, was made.

Field observations. The cultures were observed closely from the time of planting until harvesting. The percentage of germination was determined.

In the second experiment the percentage of stand was taken in the same manner as in the determination of the percentage of

germination. The living hills were counted when the canes were about a meter or more in height. At maturity the degree of tillering of the plants of the different treatments was determined by counting the number of millable and non-millable stalks of 100 stools taken at random from each plot. A cane shoot or stalk which measured about one meter and less from the ground to the last visible node was considered non-millable.

Harvesting, curing, and determination of yield of leguminous crops: *Peanut.* When the pods were matured, they were harvested by being dug up with a spading fork and allowed to dry. Then the pods were picked off, and the hay and nuts weighed separately.

Soybean. When the pods were matured, the soybeans were harvested by cutting the plants at the base and piling them up to dry. When dried, they were threshed by being beaten with a pole, and the seeds were winnowed. The beans and hay were weighed separately. The dried weight of the whole plant with the pods minus the weight of the cleaned beans was taken as the weight of the hay.

Harvesting and determination of the yield of the cane crop. The cane in each plot was harvested in the usual way, and the weight recorded. It was milled in the U. P. Sugar Mill, and a composite sample of the crusher juice from each plot was analyzed with the help of the Sugar Technology Division, Department of Agricultural Chemistry. The degree Brix and percentage of polarization were recorded. From these data the apparent purity, piculs sugar per ton cane, and piculs sugar per hectare of each plot were determined according to the *Methods of Chemical Control for Cane Sugar Factories,* published by the Association of Hawaiian Sugar Technologists in 1931.

Other important observations. The relative vigor of cane and weediness of the different plots were also noted. Likewise, the attacks on the plants in each plot by major pests and diseases, lodging of the canes, and earliness of maturity were closely observed.

RESULTS AND DISCUSSION

The results obtained from these experiments are presented in tables 1 to 7.

Percentage of germination. Table 1 shows the percentage of germination under the different treatments obtained in the first experiment. The fertilized plots had the highest percentage of ger-

mination with an average of 93.53 ± 0.42 per cent, and those intercropped with legumes had the lowest with averages of 75.49 ± 1.10 and 79.34 ± 1.28 per cent for peanut and soybean intercropped plots, respectively. That the intercropped plots had a much lower percentage of germination than the control may be due to the legumes utilizing most of the moisture in the soil for their germination and growth.

The legumes germinated about three weeks earlier than the sugar cane. Evidently the legumes competed with the sugar cane for the limited amount of moisture in the soil.

The comparative percentages of germination and stand of plants under the different treatments obtained in the second experiment are shown in table 2. The plots fertilized with ammonium sulfate gave significantly higher percentages of germination and stand than either those intercropped with legumes or the control. No significant difference occurred, however, in the percentages of germination and stand of plants of the intercropped plots and the control.

As a whole the results obtained in the two experiments showed that ammonium sulfate affected favorably the germination of the seed pieces, probably owing to absorption of moisture from the surrounding area. This was sufficient for the germination of the dormant buds.

Relative abundance of weeds. The weeds, which grew more or less at the same time as the legumes, were most abundant in the plots fertilized with ammonium sulfate. In the plots intercropped with legumes, there were relatively few weeds. Those that predominated at the early stage of the experiment were: *Ipomoea triloba* Linn., kulitis (*Amaranthus spinosus* Linn.) and some aguiñgay (*Rottboellia exaltata* Linn.). Later, when the canes were tall, the weeds that abounded were the aguiñgay and the butterfly pea [*Centrosema plumieri* (Turp.) Benth.], a leguminous vine which entwined the canes.

Vigor of plants and other important observations. In the two experiments the leguminous plants, especially the peanut, were very vigorous from the start. The legumes covered most of the spaces in the row between the canes and outgrew them. They hindered the growth of the weeds and the canes.

At about maturity, the peanut leaves were attacked by a leaf spot disease caused by *Cercospora personata* (B. and C.) E. and E. This defoliated some of the peanut plants.

When the peanut pods were dug up, some of the weeds were also uprooted, and some cane stalks were broken.

The canes in the plots fertilized with ammonium sulfate were the most vigorous. They had broad, dark green leaves. The canes intercropped with legumes were stunted because they were outgrown by the legumes.

Comparative degrees of tillering of plants. In the second experiment the comparative degrees of tillering of the plants were recorded as shown in table 3. The plants fertilized with ammonium sulfate gave significantly the highest number of millable stalks. These results clearly demonstrate that ammonium sulfate has a beneficial effect on the production of millable stalks of sugar cane. The plants of the control plots gave significantly more millable stalks per stool than those with peanut as an intercrop. This detrimental effect of peanut may be explained by the fact that the peanut plants outgrew the canes and covered them in their early growth. The result was that the canes were stunted. It seems probable that the peanut plants competed with the sugar cane for the available moisture and nutrient materials in the soil.

Table 3 also shows that neither ammonium sulfate nor the legumes had any effect upon the production of non-millable stalks of sugar cane, as there was no significant difference in the number of non-millable stalks produced by plants under the different treatments.

Comparative yields of cane and sugar and sugar per ton cane: Results of the first experiment. The comparative average yields of cane and sugar and sugar per ton cane obtained in the first experiment are shown in table 4. The plots fertilized with ammonium sulfate gave the highest yield of cane per hectare with an average of 78.14 $\pm$ 2.24 tons. Those intercropped with peanut gave the lowest, with an average yield of 58.58 $\pm$ 3.41 tons. No significant differences occurred, however, between the yields of the plots fertilized with ammonium sulfate and intercropped with legumes on one hand and those of the control on the other. Likewise there was no significant difference between the yields of cane of the plots intercropped with peanut and those intercropped with soybean. But the plots fertilized with ammonium sulfate gave significantly higher yields of cane than those intercropped with peanut and soybean.

Table 4 also shows that the control plots gave the highest yield of sugar, and those intercropped with soybean, the lowest. The plots intercropped with peanut and soybean gave a significantly

lower yield of sugar than either those fertilized with ammonium sulfate or the control. No significant difference occurred in the yield of sugar between the plots fertilized with ammonium sulfate and the control. Likewise, the difference in the yield of sugar of the plots intercropped with peanut and those intercropped with soybean was insignificant.

Table 4 further shows that the application of ammonium sulfate and intercropping with peanut lowered significantly the yield of sugar per ton cane. However, intercropping with soybean did not affect the yield of sugar per ton cane.

Results of the second experiment. In table 5 the comparative average yields of cane and sugar and sugar per ton cane under the different treatments can be seen. The plots fertilized with ammonium sulfate gave the highest average yield, with 77.11 ± 1.35 tons cane per hectare; they gave a significantly higher yield of cane than any of the other treatments including the control. Those with peanut as an intercrop gave the lowest yield, with an average of 56.94 ± 2.57 tons per hectare. The plots with peanut as an intercrop gave a significantly lower yield of cane than any of the other treatments, including the control.

Table 5 also shows that the plots fertilized with ammonium sulfate gave the highest yield of sugar with an average of 125.01 ± 4.25 piculs per hectare, and those intercropped with peanut the lowest, with an average of 96.00 ± 1.98 piculs per hectare. The plots fertilized with ammonium sulfate gave a significantly higher yield of sugar than any other treatment, including the control. When the average yields of sugar of the different treatments were compared, however, the differences were found to be insignificant. No significant difference in the average yield of sugar per ton cane between the different treatments occurred; this shows that neither ammonium sulfate nor the legumes had affected the sucrose content of the cane in this experiment.

As a whole the results obtained in these two experiments agree with the findings of Capili[3]; namely, that ammonium sulfate had a decided beneficial effect upon the yields of cane and sugar, and that the plots with peanut and soybean as intercrops gave lower yields of cane and sugar than the control. The lower yields of the intercropped plots may be attributed to the fact that in the beginning the cane was out-grown by the legumes and the growth thus hindered. The legumes had more chances of absorbing plant

[3] Footnote 2.

food and moisture in the soil than the young cane. Undoubtedly the soil may be poorer in plant food materials because of the competition, and this resulted in the stunted condition of the canes. Evidently, the legumes competed with the young cane at its critical period of growth.

Venkatraman (1928) reported that in the life of the cane plant, the first three months period is one of considerable importance, sometimes quite critical. It is also probable that when the legumes were harvested, more nitrogen was removed from the soil by the plant than was returned as a constituent of the roots and adhering nodules; hence, the soil was probably poorer in plant food materials after the removal of the legumes than before the seeds were planted. In fact legumes are said to take nitrogen from the soil in the same way as other plants do. It has been reported that at the time of harvest of soybean, 74 per cent of the nitrogen is in the tops, whereas the remainder is distributed between the roots and the nodules.

Yield and value of legumes. The computed yield and value of peanut pods and soybean seeds per hectare obtained from the first and second experiments are shown in tables 6 and 7, respectively.

Table 6 shows that the plot intercropped with peanut yielded an average of 21.71 cavans per hectare. With ₱3.25 assumed as the price per cavan, this yield was valued at ₱70.58. From the soybean intercropped plots, an average of 3.87 cavans of clean seeds per hectare was produced, valued at ₱48.37, with ₱12.50 assumed as the market price per cavan.

In table 7 it may be seen that the plots intercropped with peanut yielded an average of 23.55 cavans valued at ₱76.37. An average of 1.78 cavans of clean beans per hectare valued at ₱22.25 were produced from the soybean intercropped plots.

The yield of peanut pods and soybean seeds obtained in this study cannot be regarded as normal owing to the poor growth of the plants, the damage by rats upon the soybean seeds, and the fact that some plants did not produce pods. This yield cannot be compared favorably with results obtained from pure peanut or soybean cultures. The initial controlling effect, however, upon the growth of weeds by the legumes, and the cash income from the harvested peanut and soybean, while waiting for the main crop, are of value, especially in times of low sugar prices. The income from the peanut and the soybean would, of course, increase the total income without additional cost of land preparation and cultivation and additional land.

SUMMARY AND CONCLUSIONS

1. Ammonium sulfate affected the germination of sugar cane favorably, but the legumes affected it unfavorably.

2. The plots fertilized with ammonium sulfate produced the most vigorous plants; those intercropped with legumes had stunted cane plants. The legumes, however, partly checked the growth of weeds.

3. Ammonium sulfate increased the number of millable stalks produced. Peanut had a depressing effect upon the production of millable stalks. The number of non-millable stalks was practically the same in the different treatments, including the control.

4. Ammonium sulfate had a decided beneficial effect upon the yields of cane and sugar, whereas the intercrops had a detrimental effect.

5. Neither ammonium sulfate nor the legumes affected the sucrose content of the cane.

6. The average income from peanut pods ranged from ₱70.58 to ₱76.37, and that from soybean seeds from ₱22.25 to ₱48.37.

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TABLE 1

Comparative percentage of germination under the different treatments (first experiment)

TREATMENT	GERMINATION	
	Average	Difference
	per cent	*per cent*
Control	88.98 ± 0.60	
Peanut	75.49 ± 1.10	13.49 ± 1.25
Soybean	79.34 ± 1.28	9.64 ± 1.42
Ammonium sulfate	93.53 ± 0.42	−4.55 ± 0.73
Ammonium sulfate [a]	93.53 ± 0.42	
Peanut	75.49 ± 1.10	18.04 ± 1.17
Soybean	79.34 ± 1.28	14.19 ± 1.34
Peanut	75.49 ± 1.10	
Soybean	79.34 ± 1.28	−3.85 ± 1.68

[a] Ammonium sulfate was used as basis for comparison.

TABLE 2

Comparative percentages of germination and stand of plants under the different treatments (second experiment)

TREATMENT	GERMINATION		STAND	
	Average	Difference	Average	Difference
	per cent	*per cent*	*per cent*	*per cent*
Control	78.06 ± 0.53		74.96 ± 0.49	
Peanut	78.28 ± 0.77	0.22 ± 0.93	73.24 ± 1.27	1.72 ± 1.36
Soybean	77.44 ± 0.57	0.62 ± 0.78	72.64 ± 1.21	2.32 ± 1.31
Ammonium sulfate	81.64 ± 0.59	3.58 ± 0.79	78.71 ± 0.63	3.75 ± 0.86
Ammonium sulfate [a]	81.64 ± 0.59		78.71 ± 0.63	
Peanut	78.28 ± 0.77	3.36 ± 0.97	73.24 ± 1.27	5.47 ± 1.42
Soybean	77.44 ± 0.57	4.20 ± 0.82	72.64 ± 1.21	6.07 ± 1.37
Peanut	78.28 ± 0.77		73.24 ± 1.27	
Soybean	77.44 ± 0.57	0.84 ± 0.96	72.64 ± 1.21	0.60 ± 1.75

[a] Ammonium sulfate was used as basis for comparison.

TABLE 3

Comparative degree of tillering of plants under the different treatments (second experiment)

TREATMENT	NUMBER OF STOOLS OBSERVED	AVERAGE NUMBER OF MILLABLE STALKS PER STOOL	DIFFERENCE	AVERAGE NUMBER OF NON-MILLABLE STALKS PER STOOL	DIFFERENCE
Control	500	4.03 ± 0.08		0.68 ± 0.01	
Peanut	500	3.63 ± 0.08	0.40 ± 0.11	0.79 ± 0.05	0.11 ± 0.05
Soybean	500	3.80 ± 0.07	0.23 ± 0.10	0.70 ± 0.03	0.02 ± 0.03
Ammonium sulfate	500	4.80 ± 0.06	0.77 ± 0.10	0.64 ± 0.24	0.04 ± 0.25
Ammonium sulfate [a]	500	4.80 ± 0.06		0.64 ± 0.24	
Peanut	500	3.63 ± 0.08	1.17 ± 0.10	0.79 ± 0.05	0.15 ± 0.25
Soybean	500	3.80 ± 0.07	1.00 ± 0.09	0.70 ± 0.03	0.06 ± 0.24
Peanut	500	3.63 ± 0.08		0.79 ± 0.05	
Soybean	500	3.80 ± 0.07	0.17 ± 0.10	0.70 ± 0.03	0.09 ± 0.06

[a] Ammonium sulfate was used as basis for comparison.

TABLE 4

Comparative average yields of cane and sugar per hectare and sugar per ton cane under the different treatments (first experiment)

TREATMENT	AVERAGE YIELD OF CANE PER HA.		AVERAGE YIELD OF SUGAR PER HA.		AVERAGE YIELD OF SUGAR PER TON CANE	
	Yield	Difference	Yield	Difference	Yield	Difference
	tons	*tons*	*piculs*	*piculs*	*piculs*	*piculs*
Control	68.07 ± 2.74		97.03 ± 1.19		1.44 ± 0.05	
Ammonium sulfate	78.14 ± 2.24	−10.07 ± 3.55	96.55 ± 4.81	0.48 ± 4.95	1.22 ± 0.03	0.22 ± 0.05
Peanut	58.58 ± 3.11	9.49 ± 4.20	60.32 ± 4.68	36.71 ± 4.82	1.02 ± 0.04	0.42 ± 0.06
Soybean	62.57 ± 1.75	5.50 ± 3.26	70.63 ± 1.30	26.40 ± 1.78	1.33 ± 0.02	0.11 ± 0.05
Ammonium sulfate [a]	78.14 ± 2.24		96.55 ± 4.81		1.22 ± 0.03	
Peanut	58.58 ± 3.11	19.56 ± 3.89	60.32 ± 4.68	36.23 ± 6.71	1.02 ± 0.04	0.20 ± 0.05
Soybean	62.57 ± 1.75	15.57 ± 3.96	70.63 ± 1.30	25.92 ± 4.98	1.33 ± 0.02	−0.11 ± 0.03
Peanut	58.58 ± 3.11		60.32 ± 4.68		1.02 ± 0.04	
Soybean	62.57 ± 1.75	−3.99 ± 3.63	70.63 ± 1.30	−10.31 ± 5.03	1.33 ± 0.02	−0.31 ± 0.04

[a] Ammonium sulfate was used as basis for comparison.

TABLE 5

Comparative average yields of cane and sugar per hectare and sugar per ton cane under the different treatments (second experiment)

TREATMENT	COMPUTED AVERAGE YIELD OF CANE PER HECTARE	DIFFERENCE	COMPUTED AVERAGE YIELD OF SUGAR PER HECTARE	DIFFERENCE	COMPUTED AVERAGE YIELD OF SUGAR PER TON CANE	DIFFERENCE
	tons	*tons*	*piculs*	*piculs*	*piculs*	*piculs*
Control	70.32 ± 0.78		103.45 ± 5.45		1.49 ± 0.07	
Peanut	56.94 ± 2.57	13.38 ± 2.69	96.00 ± 1.98	7.45 ± 5.80	1.71 ± 0.06	−0.22 ± 0.09
Soybean	66.53 ± 1.84	3.79 ± 2.00	96.52 ± 5.45	6.93 ± 7.71	1.46 ± 0.10	0.03 ± 0.12
Ammonium sulfate	77.11 ± 1.35	−6.80 ± 1.56	125.01 ± 4.25	−21.56 ± 6.91	1.61 ± 0.05	−0.13 ± 0.09
Ammonium sulfate [a]	77.11 ± 1.35		125.01 ± 4.25		1.62 ± 0.05	
Peanut	56.94 ± 2.57	20.17 ± 2.90	96.00 ± 1.98	29.01 ± 4.69	1.71 ± 0.06	−0.09 ± 0.08
Soybean	66.53 ± 1.84	10.58 ± 2.28	96.52 ± 5.45	28.49 ± 6.91	1.46 ± 0.10	0.16 ± 0.11
Peanut	56.94 ± 2.57		96.00 ± 1.98		1.71 ± 0.06	
Soybean	66.53 ± 1.84	−9.60 ± 3.16	96.52 ± 5.45	−0.52 ± 5.80	1.46 ± 0.10	0.25 ± 0.12

[a] Ammonium sulfate was used as the basis for comparison.

TABLE 6

Computed yields and value of peanut in pods and soybean seeds per hectare (first experiment)

PLOT NUMBER	PEANUT		SOYBEAN	
	Yield in cavans	Value in pesos [a]	Yield in cavans	Value in pesos [b]
1	22.61	73.48	5.35	66.87
2	17.85	58.01	3.21	40.12
3	16.36	53.17	3.57	44.62
4	25.29	82.19	3.92	49.00
5	26.48	86.06	3.33	41.62
Average	21.71	70.58	3.87	48.37

[a] One cavan of peanut costs ₱3.25.
[b] One cavan of soybean costs ₱12.50.

TABLE 7

Computed yields and value of peanut in pods and soybean seeds per hectare (second experiment)

PLOT NUMBER	PEANUT		SOYBEAN	
	Yield in cavans	Value in pesos [a]	Yield in cavans	Value in pesos [b]
1	33.68	109.46	2.70	33.75
2	21.38	69.48	1.16	14.50
3	17.56	57.07	1.55	19.38
4	20.24	65.78	1.52	19.00
5	24.89	80.89	1.97	24.63
Average	23.55	76.37	1.78	22.25

[a] One cavan of peanut costs ₱3.25.
[b] One cavan of soybean costs ₱12.50.

EFFECTS UPON THE CARBON-NITROGEN RATIO IN LEAVES OF RICE GROWN IN LIPA CLAY LOAM SUPPLIED WITH VARYING AMOUNTS OF AMMONIUM SULFATE [1]

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WITH TWO TEXT FIGURES

Available literature shows that the application of suitable amounts of ammonium sulfate to Lipa clay loam always brings about good growth and relatively high yield of upland rice plant. The yield of top increases with the amount of the fertilizer used and a liberal application of ammonium sulfate results in a delay in fruiting and uneven ripening of grains. Almeda (1937) suspected that this was "caused by the presence in the leaves of an insufficient amount of mineral and nitrogenous salts in proportion to the amount of carbohydrate that the leaves of the older plants can produce photosynthetically." He suggested that the carbon-nitrogen ratio, found essential for the production of fruits in certain plants might be wanting in full-grown rice plants liberally fertilized with sulfate of ammonia. It was this suggestion that prompted this study.

Various workers (Soriano, 1934; Almeda, 1937; Talamisan, 1938; and Mamañgon, 1938) found that the liberal application of ammonium sulfate to Lipa clay loam resulted in luxuriant vegetative growth of rice at the expense of the yield of grains. Soriano (1934) reported that the moisture and the chlorophyll contents increased with the amount of ammonium sulfate used and decreased with the age of the plants. Libatique (1931) observed that the fertilized plants had shorter roots than the control. Almeda (1937) noted that as the rice plant received more ammonium sulfate, more dry matter was produced, and that the percentage of ash in tops diminished with the age of the plant and with the amount of the fertilizer used.

Enrile (1938) found that the Lipa clay loam he employed did not lack potash to produce good growth of rice plants. Similarly, Talamisan (1938) found that the soil was not short in phosphoric

[1] Experiment Station contribution No. 1357.

acid and contended that apparently harmful effects upon rice plants of the excess of sulfate of ammonia could not be due to lack of phosphorous or phosphate in the soil.

Kelly and Thompson (1910) found that the rice plant contained 2.17 per cent N, 0.89 per cent P_2O_5, and 3.07 per cent K_2O during its early growth; but the percentage of these nutrient materials diminished during the later development of the plant. In the later stage, the plant was found to contain 0.86 per cent N, 0.53 P_2O_5, and 1.25 per cent K_2O.

Hicks (1928) studied the C/N ratio of winter shoots of *Salix viminalis* and found that shoots grew well at the area of lowest C/N ratio (4.8) and roots at higher (18.8). His experiments on the regeneration of cuttings of this plant were carried out with normal cuttings and with cuttings injected with potassium nitrate and various sugars. He found 1.63 per cent N in the bast and 5.74 per cent in the buds and contented that the initiation of growth was due to stimulated respiration, giving energy for the withdrawal of nitrogen into the bast and its consequent upward translocation, particularly to the buds. It was found that excess in potassium nitrate prevented the commencement of growth.

The growth of several species of seedlings in relation to available nitrogen and carbon was observed by Reid (1929). From his results, it was found that when grown without nitrogen from an outside source, the seeds that had a high nitrogen and relatively low carbon content produced seedlings with a large top in proportion to the roots. But seeds that had a low nitrogen and a high carbon content produced seedlings with a relatively small top in proportion to the size and weight of roots.

Kraus and Kraybill (1918) noted that there was a descending gradient of total nitrogen and moisture in the tomato plant. The upper stem was found to contain 2.75 per cent N and 93.4 per cent moisture, while the lower stem contained 1.37 per cent N and 90.01 per cent moisture. There was an ascending gradient in total dry matter, polysaccharides, and sucrose. The upper stem was found to contain 6.51 per cent dry matter, 3.75 per cent polysaccharides, and 0.0 per cent sucrose; whereas the lower stem contained 9.99 per cent dry matter, 4.34 per cent polysaccharides, and 0.46 per cent sucrose.

Objects of this study

This study was undertaken with the following objects: (*a*) to determine the effects upon the carbon-nitrogen ratio in leaves of

rice plant when grown in Lipa clay loam supplied with varying amounts of ammonium sulfate, (*b*) to observe the effects upon the general vigor of the plants and the yield of grains of varying the amounts of the fertilizer used.

Time and place of this study

The culture part of this study was conducted in the experimental yard of the Department of Agricultural Botany. It was begun on July 22 and ended on December 17, 1938. Part of the work, especially the determination of carbon and nitrogen in the leaves, was done in the Department of Agricultural Chemistry from September, 1938, to February, 1939, under the supervision of Mr. Leopoldo J. Villanueva of that Depatrment.[2]

MATERIALS AND METHODS

The plant

Upland rice plants, variety Inintiw, were used. The seeds obtained from the Department of Agronomy were soaked overnight in water and planted six to each pot. When the seedlings were one week old, some of them were pulled up leaving two plants of apparently uniform development in each pot.

The soil

The soil used was Lipa clay loam. It was gathered from a lot behind the Administration Building of the College. It was pulverized, sifted, and mixed thoroughly. About eighteen kilograms of soil were placed in each pot. This soil was found to contain 0.13 per cent N, 0.20 per cent P_2O_5, and 0.37 per cent K_2O (Enrile, 1938).

The cultures and fertilizers used

Ammonium sulfate containing 20.6 per cent nitrogen was used. Ten grams, eight grams, six grams, four grams, and two grams were separately applied to the pots. Unfertilized cultures were included as checks. There were two sets of cultures, each set consisting of six quadruplicate cultures. Both sets were run at the same time. The plants from set I were grown to maturity for the yield of grains. Those from set II were used for the C/N ratio determination. They were harvested soon before flowering. The blades of the leaves from

[2] Grateful acknowledgment is hereby made for the facilities which that department extended and for the supervision which Mr. L. J. Villanueva gave.

each culture were gathered and their fresh weight, moisture content, and dry weights determined.

Care of the culture

The cultures were exposed to the sun in the experimental yard of the Department of Agricultural Botany. They were cultivated and watered as often as necessary. Care was taken to protect them from insect pests and fungous disease.

Chemical analysis

The total nitrogen content of leaves was determined in accordance with the Official and Tentative Methods of Analysis of the Association of Agricultural Chemists of America (1931) with a modified ammonia bulb introduced by Villanueva (1933). The total carbon

Fig. 1.—Rice plants, 63 days old, grown in Lipa clay loam supplied with varying amounts of ammonium sulfate. Cultures I (control), no fertilizer; II, 2 grams; III, 4 grams; IV, 6 grams; V, 8 grams; VI, 10 grams. Cultures from September 10 to December 17, 1938. Photograph by the Photographic Division, College of Agriculture.

was determined in accordance with Winters and Wimer's method (1931) with some modifications as described by Villanueva and Lumang (1936).

EXPERIMENTS AND RESULTS

Description of the experiments

The two sets of pot cultures were started on July 22, 1938; each set consisted of six quadruplicate cultures supplied with varying amounts of sulfate of ammonia. The plants in one set produced mature seeds and were harvested on October 31, 1938. The plants in the other set were gathered a little earlier when they were seventy

days old. Their leaves were analyzed for carbon and nitrogen contents needed for the determination of the carbon-nitrogen ratio in leaves.

These experiments were repeated, two similar sets of cultures being again started on September 10, 1938. One set (fig. 1) was harvested on December 17, 1938, when the grains had reached full maturity. The leaves of the plants in the other set (fig. 2) were gathered earlier, on November 12, 1938, and were employed for the determination of the carbon-nitrogen ratio.

The average experimental data [3] obtained from the first two sets of cultures are given in tables 1 and 2, whereas those for the two later sets are shown in tables 3 and 4.

Fig. 2.—Mature rice plants, grown in Lipa clay loam supplied with varying amounts of ammonium sulfate. Cultures I (control), no fertilizer; II, 2 grams; III, 4 grams; IV, 6 grams; V, 8 grams; VI, 10 grams. Cultures from September 10 to December 17, 1938. Photograph by the Photographic Division, College of Agriculture.

Number of bearing and non-bearing culms. The bearing and non-bearing culms of the two plants in each pot were counted at the time of harvest. The average data in tables 1-4 were obtained.

Dry weight of empty and full grains. The panicles from each culture were first dried in the sun and then in an electric oven to a constant weight and weighed. The rice grains were placed in water in a beaker and stirred with a glass rod. Those that floated were collected and dried in the oven to constant weight. The weight of the full-grains from each culture was obtained by subtracting the

[3] The original data are on file in the Department of Agricultural Botany.

weight of the empty grains from the weight of all the grains from that culture.

Air dry weight of top. After the grains were harvested, the plants from each culture were cut close to the roots, bundled, and labeled. The top was first dried in the sun and later in the electric oven to constant weight. The dry weight of top was obtained by adding the weight of empty grains, the weight of full grains, and the weight of culms and leaves. The total dry weights of tops obtained from the four similar cultures were averaged.

The weather data

A general idea of the climatic conditions that prevailed during the progress of this study may be obtained from the weather data that were gathered by the Department of Agricultural Botany for the College. The earlier months, from July to September, were somewhat warm and dry. The maximum temperature during the months of September and October was 31.30°C. The average rainfall for the month of July was 8.53 inches and 18.25 inches for November. The average wind velocity for July was 49.4 miles during the day time. These weather data are given here merely to show the condition of the weather when the experiment was undertaken.

DISCUSSION OF RESULTS

Effect on rice plants of varying amounts of ammonium sulfate

As shown in figures 1 and 2, the rice plants grown in Lipa clay loam and fertilized with varying amounts of ammonium sulfate were taller, more vigorous, and had darker green leaves than the control, or unfertilized plants. These findings corroborate the observations previously reported by Almeda (1937), Enrile (1938), Talamisan (1938), and others. The intensity of the green color of leaves (fig. 1 and 2), and the dry weight of tops (tables 1 and 3) increased with the amount of ammonium sulfate employed.

The beneficial effects on the plants are the same when other criteria of results, such as number of bearing culms and the amount of full grains, are considered. Under these criteria, the yield values obtained increased, although only gradually, with the application of the fertilizer (tables 1 and 3). The slight decrease in the rate of increments in the number of bearing culms, dry weight of tops, and dry weight of full grains—not commensurate with the amount of ammonium sulfate employed—seemed to begin with culture V which received eight grams of the fertilizer per pot (tables 1 and 3). Of course, this decrease in yield values is in accord with the law of dim-

ishing increments of yields. But the basic cause may be found elsewhere—possibly in the carbon-nitrogen ratio in the leaves of the rice plants, to be discussed elsewhere in this report, as revealed by the data on hand.

The increase in yield values of such undesirable features as the number of non-bearing culms and the dry weight of empty grains was also influenced by the amount of fertilizer employed. In a general way, the greater the application of ammonium sulfate, the greater was the number of non-bearing culms and the amount of empty grains produced (tables 1 and 2). Although apparently not governed by the law referred to above, these increases in undesirable plant characters may find suitable explanation also in the carbon-nitrogen ratio in the leaves of the rice plants.

Influence on the nitrogen content of fresh leaves

The nitrogen content of fresh leaves of the rice plants increased as the amount of ammonium sulfate added to Lipa clay loam was increased. The range of nitrogen content was from 0.617 per cent in culture II to 1.078 per cent in culture VI (table 2). Similar results were obtained from the second set, and, in the same order, the range was from 0.513 to 0.985 per cent (table 4). In either set of cultures was the percentage of nitrogen in the fresh leaves, obtained from the control or unfertilized cultures, found to be greater than that from any of the fertilized cultures (tables 2 and 4).

Effects on the nitrogen content of leaves, moisture free

As was to be expected, the percentage of nitrogen in rice leaves, moisture free, was greater than the percentage of nitrogen in the fresh leaves of the same plant. But in both cases, the nitrogen content of the leaves increased with the application of the fertilizer. In the leaves, moisture free, of the fertilized plants, the nitrogen contents ranged from 1.51 to 3.18 per cent in the first set of cultures (table 2). In the second set of cultures, the nitrogen contents ranged from 1.56 to 3.02 per cent. In both sets, the nitrogen content of the leaves of the control, or unfertilized plants, was always lower than that of any of the plants that received additional supply of ammonium sulfate in Lipa clay loam. The leaves of the unfertilized plants contained 1.32 and 1.34 per cent of the nitrogen in the first and the second culture trials, respectively (tables 2 and 4).

Effects on the carbon content of rice leaves

The data on hand show that the leaves of the control, or unfertilized rice plants, contained the highest percentage of carbon, be-

ing 35.38 per cent in the first culture trial (table 2) and 35.44 per cent in the second trial (table 4) In these two tables are also shown conclusive evidences that the application of ammonium sulfate to Lipa clay loam brought about a decrease in the percentage of carbon in the leaves of the rice plants from the different cultures. The higher the application of the fertilizer, the smaller was the percentage of carbon in the leaves (tables 2 and 4). From the lowest to the highest amount of ammonium sulfate tried, the carbon contents of the leaves, moisture free, ranged from 33.50 to 22.36 per cent in the first set of cultures (table 2), whereas in the second set, the carbon contents ranged also from 33.50 to 22.31 per cent.

Carbon-nitrogen ratio in leaves

The progressive decreases in the percentages of carbon from cultures I to VI and the progressive increments of nitrogen in the same order necessarily would result in marked progressive variations in the ratios of carbon to nitrogen in the leaves. Evidently this was the case. In table 2, the C/N ratios in the leaves of the plants from cultures I to VI ranged in the first set from 26.80 to 7.03 per cent. In the same order, the C/N ratios in the leaves of the plants from the second set ranged from 26.45 to 7.39 per cent (table 4).

In other words, the highest ratio of carbon to nitrogen in the leaves of the rice plants in each set of cultures was obtained from the control, or unfertilized culture. Applications of ammonium sulfate to Lipa clay loam brought about decreases in C/N ratios. The greater the application of the fertilizer, the smaller was the C/N ratio in the leaves of the rice plants.

A probable cause of the harmful effects on rice plants of the liberal application of ammonium sulfate

It is a well known fact in plant nutrition that the presence in the soil of an excess amount of any nitrogenous nutrient usually results in a delay of flowering or of fruiting of any plant. Upland rice plants when supplied with a liberal amount of ammonium sulfate have been observed by a number of local workers, notably Libatigue (1931), Soriano (1936), and Almeda (1937), to behave in a similar manner. Almeda rightly considered these results as harmful effects upon rice plants and specified them as "late flowering and consequently late fruiting, the comparatively low yield of grain, and the variable time of ripening of grains."

In speculating upon the cause of the harmful effects referred to, Almeda (1937) apparently erred when he tentatively concluded, that

the cause was "the presence in the leaves of an insufficient amount of mineral and nitrogenous salts in proportion to the amount of carbohydrate that the leaves of the older plants can produce photosynthetically."

Almeda (1937), of course, had not determined the carbon and nitrogen contents of the fertilized and unfertilized plants; consequently, he had no data on the C/N ratio of the leaves. His tentative conclusion was based only on the size of tops and root system and on the amount or percentage of dry matter and ash content of tops. He made a very good suggestion, however, when he pointed out that "the carbon-nitrogen ratio found so essential for the production of fruits in certain plants might be wanting in full-grown rice plants liberally fertilized with sulfate of ammonia."

In the present study, however, as suggested by Almeda, the carbon and the nitrogen contents (as percentages) of the leaves of rice plants grown in Lipa clay loam and supplied with varying amounts of ammonium sulfate were determined. The main objects were to determine the C/N ratios in the leaves and to correlate these with the yield data obtained from the different cultures. It was, therefore, expected that these data might throw some light upon real cause of the apparently harmful effects upon the growth and yield of rice plants when liberally supplied with ammonium sulfate.

Owing to physical impossibility, the highest fertilizer application tried in the present study was only 10 grams per culture. No attempt was made to gather data on rate of flowering, rate of maturity of grains, and size of grains. Fortunately, however, a colleague [4] in this Department was able to show beyond any reasonable doubt specific data on these. He found that the application of ammonium sulfate to Lipa clay loam at the rates exceeding 10.56 grams per pot not only markedly delayed flowering and maturity of grains, but also resulted in diminished size and yield of grains. In the latter case, the greater the application of the fertilizer, the greater was the depressive effects obtained.

Now, from the preceding study of the data on hand, it was revealed that the liberal application of ammonium sulfate to Lipa clay loam was conducive to a greater accumulation (and probably absorption also) of nitrogen in the leaves of the rice plants. This might, of course, be expected, and would explain why taller plants with darker green leaves were always produced. On the other hand, it

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[4] LUSANANDANA, BHAKDI. Effects upon rate of maturity and size of grain of rice grown in Lipa clay loam supplied with varying amounts of ammonium sulfate. (Unpublished, 1939).

was noted that the application of the fertilizer to the same soil produced depressive effects on the carbon content (percentage on dry basis) of the leaves of the same plants. Since the production of grains largely depends upon the carbon contents of the leaves, it is to be expected that the increase in the number of empty grains, the decrease in the number of filled grains, and the slight decrease in the size of the grains, as observed by Lusanandana following the liberal application of ammonium sulfate, would occur.

But why the delay in flowering and maturity of grains, and the uneven ripening of the latter? These cases are in full accord with the experience of farmers and may probably be explained as mainly due to the presence of protein in the leaves of the rice plants liberally fed with ammonium sulfate, the principal growth-promoting substance of plants.

It may be recalled that the ratio of carbon to nitrogen decreased with the amount of the fertilizer employed. If this fact is correlated with the harmful effects referred to, it might be possible to conclude that a C/N ratio in the leaves below a certain amount is harmful to the rice plants. But what this harmful point is, the present data, being gathered not from the point of view of agronomy, could not definitely show. There was, however, a close agreement between the good stands and high yields of the plants from the cultures that received ammonium sulfate not exceeding 10 grams and those of Lusanandana's culture which received not exceeding 10.56 grams. Moreover, Lusanandana found that the application of the fertilizer beyond this amount produced the harmful effects expected. Therefore, it is probable that a C/N ratio below 7 in the leaves of rice plants grown in Lipa clay loam and liberally fertilized with ammonium sulfate was responsible for "the delayed flowering and consequently delayed fruiting, the comparatively low yield of grain, and the variable time of ripening of grains."

SUMMARY AND CONCLUSIONS

1. The number of green leaves and dry weight of tops of upland rice plants increased with the amount of ammonium sulfate added to Lipa clay loam.

2. The nitrogen content of the leaves of rice, both fresh and moisture-free samples, increased as the amount of ammonium sulfate added to Lipa clay loam was increased.

3. The carbon contents of leaves of rice plants decreased with the amount of ammonium sulfate used; these ranged from 33.50 to

22.26 per cent in the first set and from 33.50 to 22.31 per cent in the second set.

4. The C/N ratios in the leaves of the plants from cultures I to VI ranged from 26.80 to 7.03 per cent in the first set of cultures and from 26.45 to 7.39 per cent in the second set.

5. The highest C/N in the leaves of the rice plants in each set of cultures was obtained from the control, or unfertilized culture.

6. The application of ammonium sulfate to Lipa clay loam brought about decreases in C/N ratios. The greater the application of the fertilizer, the smaller was the C/N ratio in the leaves of the rice plants.

7. The delay of flowering and maturity of grains, and the uneven ripening of the latter may probably be attributed to the presence of protein in the leaves of the rice plants liberally fed with ammonium sulfate. Protein is the principal growth-promoting substance of plants.

8. It may be possible to conclude that a carbon-nitrogen ratio below 7 in the leaves of rice plants grown in Lipa clay loam and liberally fertilized with ammonium sulfate was responsible for "the late flowering and consequently late fruiting, the comparatively low yield of grain, and the variable time of ripening of grains."

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TABLE 1

Average data from rice grown in Lipa clay loam in pots supplied with varying amounts of ammonium sulfate [a]
(Cultures from July 22, 1938, to October 31, 1938)

CULTURE NO.	AMOUNT OF AMMONIUM SULFATE USED	NUMBER OF BEARING CULMS	NUMBER OF NON-BEARING CULMS	DRY WEIGHT OF		
				Tops	Empty grains	Full grains
	grams			*grams*	*grams*	*grams*
I	0	7.25	1.25	22.22	0.80	9.96
II	2	13.50	2.00	39.46	0.94	19.33
III	4	18.00	4.75	62.46	1.55	23.93
IV	6	24.50	3.75	96.04	2.51	37.83
V	8	26.25	4.00	124.51	3.55	46.99
VI	10	25.75	6.00	135.19	4.33	46.43

[a] The original data are on file in the Department of Agricultural Botany.

TABLE 2

Average nitrogen and carbon contents of leaves of rice grown in Lipa clay loam in pots supplied with varying amounts of ammonium sulfate [b]
(Cultures from July 22, 1938, to September 30, 1938)

CULTURE NO.	AMOUNT OF AMMONIUM SULFATE USED	NITROGEN CONTENT OF FRESH LEAVES	NITROGEN CONTENT OF LEAVES, MOISTURE FREE	CARBON CONTENT OF LEAVES, MOISTURE FREE	RATIO OF CARBON TO NITROGEN
	grams	*per cent*	*per cent*	*per cent*	
I	0	0.454	1.32	35.38	26.80
II	2	0.617	1.51	33.50	22.19
III	4	0.647	1.88	29.49	15.65
IV	6	0.830	2.42	27.36	11.31
V	8	0.945	2.79	25.40	9.10
VI	10	1.078	3.18	22.36	7.03

[b] The original data are on file in the Department of Agricultural Botany.

TABLE 3

Average data from rice grown in Lipa clay loam in pots supplied with varying amounts of ammonium sulfate [c]

(Cultures from September 10, 1938, to December 17, 1938)

CULTURE NO.	AMOUNT OF AMMONIUM SULFATE USED	NUMBER OF BEARING CULMS	NUMBER OF NON-BEARING CULMS	DRY WEIGHT OF		
				Tops	Empty grains	Full grains
	grams			*grams*	*grams*	*grams*
I	0	6.25	0.50	19.60	1.25	8.10
II	2	12.00	2.75	36.98	1.68	14.53
III	4	17.25	3.75	63.69	2.19	25.33
IV	6	20.50	3.50	100.27	2.44	37.99
V	8	24.75	2.50	123.13	3.44	45.45
VI	10	26.75	3.75	129.52	4.27	45.43

[c] The original data are on file in the Department of Agricultural Botany.

TABLE 4

Average data on nitrogen and carbon contents of the leaves of rice grown in Lipa clay loam in pots to which varying amounts of ammonium sulfate fertilizer were added [d]

(Cultures from September 10, 1938, to November 12, 1938)

CULTURE NO.	AMOUNT OF AMMONIUM SULFATE USED	NITROGEN CONTENT OF FRESH LEAVES	NITROGEN CONTENT OF LEAVES, MOISTURE FREE	CARBON CONTENT OF LEAVES, MOISTURE FREE	RATIO OF CARBON TO NITROGEN
	grams	*per cent*	*per cent*	*per cent*	
I	0	0.450	1.34	35.44	26.45
II	2	0.513	1.56	33.50	21.47
III	4	0.653	1.99	29.55	14.85
IV	6	0.800	2.44	27.41	11.23
V	8	0.917	2.81	25.58	9.10
VI	10	0.985	3.02	22.31	7.39

[d] The original data are on file in the Department of Agricultural Botany.

STUDIES ON THE CORRELATION BETWEEN CERTAIN CHARACTERS OF BERKJALA SOWS AND THE SIZE OF THEIR LITTERS [1]

ADOLFO E. CASTILLO

WITH ONE TEXT FIGURE

The points upon which efficiency is based in the selection of pigs for breeding purposes are still far from satisfactory. Many of the points emphasized in score cards used in judging pigs are assumptions or conjectures empirically formed by experienced hogmen. Even in the United States no satisfactory bases for selection of swine breeding stock have been established (Culbertson, Evvard, Kildee, and Helser, 1930)[2]. In poultry, Fronda and Gamo (1931)[3] found certain relationships between egg production and certain characters of the head in the Los Baños Cantonese chickens. Studies were made by the writer on swine for the purpose of testing whether or not there was any relation between fertility as measured by the number of young produced and certain characters which are emphasized in the score card for selecting hogs for breeding. Data obtained from these studies would not only simplify the bases for judging swine but also help proper evaluation of the points emphasized in the score cards.

The object of this work was to determine whether or not there is any correlation between the number of pigs in the litter and the weight, condition, depth of body, and length of legs in the Berkjala sows.

The work was conducted in the Department of Animal Husbandry, from October, 1931, to October, 1933, covering a period of twenty-four months.

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[1] Experiment Station contribution No. 1358. Prepared in the Department of Animal Husbandry, under the direction of Assistant Professor Mariano Mondoñedo and Associate Professor Miguel Manresa.

[2] CULBERTSON, C. C., JOHN M. EVVARD, H. H. KILDEE, AND M. D. HELSER. 1930. Swine performance record litter comparisons. Iowa State College of Agriculture and Mechanic Arts Agric. Exper. Sta. Bull. 277: 85-115.

[3] FRONDA, F. M., AND FELIX S. GAMO. 1931. The relation of some head characters and egg production among Cantonese fowls. The Philippine Agriculturist 20: 261-268.

Materials

Complete measurements were made on 84 sows of the Department of Animal Husbandry between two and three years of age. Observations on and measurements of 19 additional sows from the beginning of the work until the conclusion of these studies were made possible; thus the total number of sows studied was raised to 103.

For measuring the animals a steel caliper and a steel tape measure were used.

Management of animals

All the sows in this study were fed and cared for in accordance with the usual practice in the Department of Animal Husbandry. The sows were encouraged to take plenty of exercise during the early period of pregnancy. As pregnancy advanced, however, exercise was gradually limited until a few days before farrowing when the sows were confined in pens. They were allowed only a limited amount of concentrate early in the period to induce them to eat more pasture feed and get more exercise. Then the amount of concentrate was gradually increased to the full allowance towards the end of gestation.

During the nursing period the sows were confined in hog pens. They were brought gradually to full feeding during the first few days after farrowing. About one kgm. of soilage daily for every 100 kgm. live weight of the animals was supplied to them up to the time of weaning.

The pigs were weaned when they were from eight to ten weeks old, depending upon their development. As a general rule, the pigs were considered ready for weaning after they had attained an average of eight to ten kgm. each.

After weaning, all the sows in the breeding herd were given liberal feeding and pasturage to improve their condition for the next breeding.

Measurements

Measurements and weighing were made before mating, before farrowing, and after farrowing. When a sow was observed to be in oestrus, the age and weight were recorded and measurements were made.

When the measurements were taken, the animals were made to stand naturally and squarely on a level floor. Two readings were generally made. Figure 1 shows the points at which measurements were made.

Length of legs. The length of the fore legs was determined by measuring the distance from the elbow perpendicularly to the floor. That of the hind shank was obtained by taking the perpendicular distance from the hock to the floor.

Height of underline. This measurement was taken at the fore flank, at the middle of the body, and at the hind flank.

Depth of body. In taking this measurement, one point of the steel caliper was applied on the breast bone at the point of attachment of the seventh rib and the other point on the back. The same measurements were made at the middle of the body and at the hind flank.

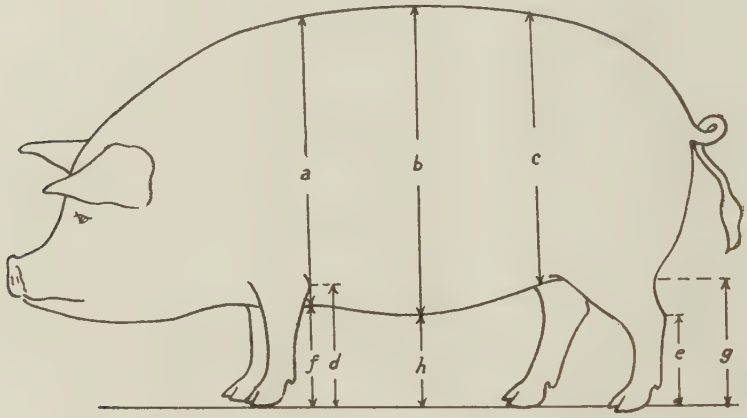

Fig. 1.—A diagram of a Berkjala sow showing the different characters studied: *a* depth of body at heart girth; *b* depth of body at middle; *c* depth of body at hind flank; *d* length of leg from elbow to floor; *e* length of leg from hock to floor; *f* distance from fore flank to floor; *g* distance from lower thigh to floor, and *h* distance from abdomen to floor.

RESULTS AND DISCUSSION

Correlations

The results obtained from the foregoing studies are summarized in table 1.

There was no significant relationship existing between the weight of the sows before mating or before farrowing and the size of their litter at birth, the coefficients of correlation being $r = 0.15 \pm 0.07$ before mating and $r = 0.17 \pm 0.06$ before farrowing. The coefficient of correlation between the weight of the sows after farrowing and the size of litter was $r = 0.21 \pm 0.06$, which is positive but low.

No correlation existed between the length of legs of the sows and size of litter as represented by the measurements taken from the point of elbow and point of hock to the floor. There was also no correlation between the height of the underline at the fore flank or hind flank and size of litter. Therefore a statement on the score cards that the legs of breeding sows should be moderately short, strong, and wide apart cannot have a bearing upon the proclivity to produce large litters.

There was, however, a high positive correlation between depth of body at chest and size of litter. The coefficients were $r = 0.59 \pm 0.05$, before mating, $r = 0.38 \pm 0.05$ before farrowing, and 0.34 ± 0.06 after farrowing. The correlation between the depth of body at the middle and the size of litter before mating was $r = 0.39 \pm 0.05$, before farrowing $r = 0.41 \pm 0.05$, and after farrowing $r = 0.40 \pm 0.05$. The coefficients of correlation between the depth of body at the hind flank and the size of litter were $r = 0.41 \pm 0.06$ before mating, $r = 0.39 \pm 0.05$ before farrowing, and $r = 0.30 \pm 0.06$ after farrowing. The existence of moderate positive correlations is a practical certainty since the correlation coefficients are more than six times their probable errors (Babcock and Clausen, 1927).[4] It may, therefore, be concluded that the depth of body of the sows, whether measured at the chest, at the middle of the body, or at the hind flank, are the characters having definite practical value in selecting sows that are to produce large litters.

Relationship between condition of the sows and size of litter

In this study, the condition of the animal was based on the degree of fatness and on its vigor. An animal that was classified thin and weak was considered of poor condition. If it was somewhat thin but fairly active, it was classified as of fair condition. Those in good condition were active and possessed a good amount of flesh without being fat. The relationship between the condition of the sows and the size of litter they produced is summarized in table 2.

Of the 84 sows studied before mating, 18 were classified as poor. These sows produced 71 pigs, or an average of 3.9 pigs a litter. Six of them gave 3 pigs to the litter, seven, 4 pigs to the litter, and five, 5 pigs to the litter.

Of the twenty-three sows which were classified as fair, only one sow gave 3 pigs to the litter and five sows 4 pigs to the litter. The

[4] Babcock, E. B., and R. E. Clausen. 1927. Genetics in relation to agriculture. 2nd ed., ix + 673 p., 203 fig. New York: McGraw-Hill Book Co., Inc.

rest, or 17 sows, gave more than 5 pigs to the litter. A total of 140 pigs were produced, averaging 6 pigs to each sow.

Forty-three sows were classified as good in condition. The majority produced 8 pigs to the litter. Only one sow gave 5 pigs to the litter, five sows 6 pigs to the litter, and nine sows 7 pigs to the litter. The rest, or 28, gave from 8 to 14 pigs to the litter. The total number of young produced was 359, or an average of 8.3 pigs each. From the foregoing results it is evident that sows bred at the time they were in good condition were much more prolific than those bred at the time their condition was fair or poor. Thompson (1921)[5] states that it is generally admitted that sows which are gaining rapidly in condition at breeding time conceive more readily and produce larger litters.

Regarding the condition of 103 sows observed before farrowing, 17 were classified as fair in condition and 86 as in good condition. None were in poor condition. The total number of pigs produced by those classified as fair in condition was 76, or an average of 4.5 pigs for each sow, while those in good condition produced 613 pigs, or an average of 7.1 pigs for each sow. Thompson (1921) reports that, from his observation during a period of three years at the California Agricultural Experiment Station, an average of 8.6 live pigs to the litter was secured from sows that the average breeder would call fat at the time of farrowing.

In this study, 103 sows were observed 70 to 80 days after farrowing or after they had weaned their pigs. Fifteen of them were classified as in poor condition, 68 in fair condition, and 20 in good condition. The average number of pigs nursed by sows classified as in poor condition was 8.7 pigs per litter; that by sows in fair condition, 6.5 pigs per litter; and that by sows in good condition, 5.6 pigs per litter. It is clear that sows with large litters suffered much in condition during the first 70 to 80 days of the suckling period, in agreement with the general observation that a sow with a large litter loses in weight even when given the best of care and feed.

The results may also be presented by giving a value of 100 per cent to the group of sows that gave the highest average number of pigs in a litter before mating. Under this system of evaluation, sows classified as fair in condition had a value of 71.28 per cent and those in poor condition, 46.98 per cent. If the values before farrowing of sows in good condition are considered as 100 per cent, those in fair condition had a value of 63.39 per cent. On the other hand, if sows

[5] Thompson, I. J. 1921. Feeding and management of hogs. California Agric. Exper. Sta. Cir. 151: 1–16.

which were in poor condition after farrowing were given a value of 100 per cent, those in fair condition had a value of 74.71 per cent and those in good condition only 64.37 per cent.

It is possible that to produce the maximum number of pigs per litter good feeding and care by which the condition of the sows is improved is necessary. The ability of the sows to raise large litters was best with those which necessarily lost weight during the nursing period owing to the larger drain the body had to undergo in raising a greater number of pigs.

SUMMARY AND CONCLUSIONS

The results of studies on the relationship between the weight, length of legs, distance from underline to floor, depth of body and condition of breeding sows and the size of their litter may be summarized as follows:

1. A very low correlation existed between the weight of the sows and the size of their litter.

2. No correlation existed between the length of legs or the distance of the underline from the floor and the size of the litter.

3. High and definitely significant positive correlation existed between the depth of body and the size of litter of the sows.

4. Sows that were in good condition at the time of mating and which maintained this condition during the period of pregnancy gave consistently larger litters than those which were in poorer condition during the same period.

5. Sows which were in poor condition after farrowing had larger litters than those which were in better condition.

TABLE 1

Correlation of some characters with fertility in Berkjala sows

CHARACTERS CORRELATED WITH SIZE OF LITTER	COEFFICIENT OF CORRELATION		
	Before mating	Before farrowing	After farrowing
Weight of sow	0.15 ± 0.07	0.17 ± 0.06	0.21 ± 0.06
Point of elbow to floor	0.02 ± 0.07	—0.12 ± 0.06	0.05 ± 0.06
Point of hock to floor	0.02 ± 0.07	—0.09 ± 0.06	0.05 ± 0.06
Fore flank to floor	0.06 ± 0.07	—0.04 ± 0.06	0.05 ± 0.06
Hind flank to floor	0.07 ± 0.07	0.04 ± 0.06	0.06 ± 0.06
Depth of body at chest	0.59 ± 0.05	0.38 ± 0.05	0.34 ± 0.06
Depth at middle of body	0.39 ± 0.05	0.41 ± 0.05	0.40 ± 0.05
Depth of body at hind flank ...	0.41 ± 0.06	0.39 ± 0.05	0.30 ± 0.06

TABLE 2

Relationship between condition and fertility of sows

CONDITION	NUMBER OF SOWS	TOTAL NUMBER OF PIGS FARROWED	AVERAGE SIZE OF LITTERS	
			Number of pigs	Percentage
Before mating				
Poor	18	71	3.9	46.98
Fair	23	140	6.0	72.28
Good	43	359	8.3	100.00
Total	84	570		
Before farrowing				
Poor	0	0	0.0	0.00
Fair	17	76	4.5	63.38
Good	86		7.1	100.00
Total	103	689		
After farrowing				
Poor	15	131	8.7	100.00
Fair	68	445	6.5	74.71
Good	20	113	5.6	64.37
Total	103	689		

AN ELSINOË ON TODDALIA [1]

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In 1931, Sydow (1931) described the new myriangiaceous genus and species *Isotexis toddaliae* on living leaves of *Toddalia asiatica* (Linn.) Lam. from Baguio, province of Benguet, Philippines. He found the spores to be muriform, whereas in the closely similar genera *Elsinoë* Rac. and *Plectodiscella* Wor. only spores with transverse walls were described. Contemporaneously with Sydow's description of *Isotexis* and *E. toddaliae,* Jenkins (1931, *also see* 1933, fig. 1, G and explanation on page 666, paragraph 1) showed that the ascospores in what is now known as *Elsinoë phaseoli* Jenkins (1933) may be muriform. In 1932, the genus *Plectodiscella* was made a synonym of *Elsinoë.* Muriform spores have been observed repeatedly in *E. phaseoli,* of which the most abundant material has been available, and they have been found in other species, e.g., in several now being described.[2] The longitudinal septation is generally found in one or both median cells of the ascospore.

Sydow's careful description of *Isotexis* and *I. todalliae* depicts in all respects a typical *Elsinoë,* as this genus is now known. Under the circumstances it is believed that *Isotexis* need no longer be segregated from that of *Elsinoë,* but should be regarded as a synonym of it. The type species *I. toddaliae* is accordingly transferred to the genus *Elsinoë* as *E. toddaliae* (Syd.).

Two other described species of *Elsinoë* known to attack rutaceous hosts are *E. fawcetti* (Jenkins) Bitancourt and Jenkins (1936a) and *E. australis* Bitancourt and Jenkins (1936b). Both are pathogenic on *Citrus,* and the latter species is known only in South America. With the genus *Citrus,* that of *Toddalia* now be-

[1] Miscellaneous contribution No. 23.

[2] BITANCOURT, A. A., AND A. E. JENKINS. Novas especies de *Elsinoë* e *Sphaceloma* sobre hospedes de importancia economica. Annos da Primeira Reuniao Sul-Americana de Botanica. (In press).

comes the fifth rutaceous genus on which a species of *Elsinoë* or *Sphaceloma* has been found. The three other genera concerned are *Hesperethusa* (1936) and *Pleiospermium* (1938), both from the Eastern Hemisphere, and *Fagara* (1938) from South America. The broad distribution of *Toddalia asiatica* in the Eastern Hemisphere is shown on a map published by Verdoorn (1926, p. 390).

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A STUDY OF TWO METHODS OF PLANTING CORN: WITH CORNPLANTER AND BY HAND [1]

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WITH TWO TEXT FIGURES

The usual method of planting corn in the Philippines, even in the important corn-growing provinces such as Cebu, Oriental Negros, Cagayan, and Isabela, is by hand. The seeds are dropped by hand in the furrows or in holes and, with the feet, are covered with soil. Because of the high cost of planting corn by hand on the College farm—it is approximately ₱4.51 per hectare, or 7.68 per cent of the total cost of production per hectare—the Department of Agronomy has been making an attempt to discover another, more economical method. This paper reports the results of one of the studies along this line.

REVIEW OF LITERATURE

It appears that only one study, that of Varona (1929)[2], on method of planting corn has been reported in the Philippines. Varona planted the Calauan strain of the Native Yellow Flint variety with a machine, commonly called a "cornplanter," and by hand. He found that a higher yield was obtained from the machine planted than from the hand planted crops. The cost of producing the machine planted crop was lower than that of the hand planted.

OBJECTS OF THE WORK

The object of this work was to study the effect on yield and cost of production of planting corn with a corn drill, or "cornplanter."

The experiments were conducted in the Experiment Station fields of the College of Agriculture, from May to September, 1938, for the wet season culture and from November, 1938, to the early part of April, 1939, for the dry season culture.

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[1] Experiment Station contribution No. 1359. Read before the Los Baños Biological Club, November 16, 1939.

[2] VARONA, A. P. 1929. A study of two methods of planting corn: with cornplanter and by hand. The Philippine Agriculturist 18: 217-224.

MATERIALS AND METHODS

Two varieties of corn were used in the experiment, namely, the Calauan strain of Native Yellow Flint and Lagkit. The seeds of Native Yellow Flint and Lagkit corn used for wet season culture were obtained from the 1938 harvest of the dry season planting, and seeds used for the dry season culture were obtained from the harvest of the 1938 wet season crop.

The drill [3] is a machine with a furrow opener into which seed is dropped continuously through a seed tube or check head from a seed box or container, usually by means of a revolving seed plate. In this experiment the type of furrow opener used was the shoe type. The size of holes or "seed cells" in the seed plates depends on the kind of seed to be drilled. The seed plate is rotated by means of a chain and gear from the covering wheel at the rear to the light-gage

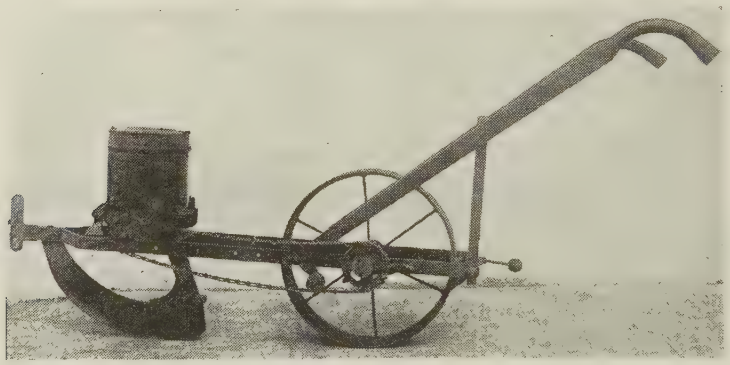

Fig. 1.—A David Bradley single-row cornplanter. Photograph by the Photographic Division, College of Agriculture.

wheel just in front of the furrow opener. A hand operated clutch is needed to disengage the sprocket chain in rotating the gear that turns the seed plate when the machine is transported.

The seed cells pass under a brush or valve which causes the seed to drop into a seed tube or check head. The rate of seeding or spacing depends on the rate of travel of seed plate and the number of cells the plate contains. To allow for different rates and spaces of planting, several plates with holes varying in size and spacing go with the drill.

The furrows where corn seed is drilled are covered by the planter wheel. The space between the rows is concave; thus when the wheel

[3] BROWNLEE, DAVIDSON J. 1931. Agricultural Machinery. x + 396 p., 600 fig. New York and London: John Wiley & Sons, Inc.

passes along the furrow, the soil is pulled together over the seed. The seed box is hinged so it can be turned over without removing the seeds from the box if a change of the seed plate is desired.

The cornplanter used in this experiment bears the name, "David Bradley Single Row," and was purchased by the College from the United States through the Bureau of Supply, Manila, at a cost of ₱33.07. (See figure 1). When this planter was bought, it had only one plate. This plate has 12 holes, 1.9 cm. each in diameter, arranged at intervals of 2.8 cm. in a circle with a radius of 5.5 cm. The seeds drop to the ground through these holes as the plate revolves when the planter is drawn by the animal. These holes allow the passage of too many seeds, 5 to 10, and cause overseeding. Usually only 2 to 3 seeds are dropped into each hole in ordinary corn planting.

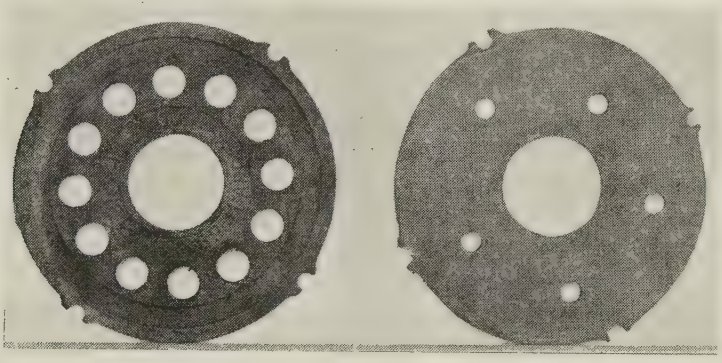

Fig. 2.—Plates used with the cornplanter illustrated in figure 1. Left, an old plate and right a home-made plate. Photograph by the Photographic Division, College of Agriculture.

To overcome this objection, a new plate was constructed in the Agronomy shop; this differs from the plate which came with the planter in having only 5 holes, which are smaller, being only 1.1 cm. in diameter, and are set farther apart, about 6.6 cm., in the circle. The home-made plate allows only 1 to 3 seeds per hole. (See figure 2).

The field used in the wet season culture has an area of 14,628 square meters. The field was divided into two equal parts. One half of the field was used for the culture of Native Yellow Flint. This half was sub-divided into three lots, each lot containing an area of 2,438 square meters. One lot was used for hand planting, the second lot for the cornplanter with plate altered, and the third lot for the cornplanter with plate unaltered.

Each of the three lots was in turn sub-divided into 5 plots, 5.3 meters by 92 meters, each equivalent to an area of 487.6 square

meters. The area and divisions and subdivisions used for Lagkit corn were similar to those used for Native Yellow Flint corn.

The field used in the dry season culture had an area of 10,886 square meters. When the field was divided, the same procedure was followed as that used in the wet season culture. The size of the lot for Native Yellow Flint was 4.8 meters by 75.6 meters, or 262.88 square meters. The same area was used for Lagkit corn.

Both the field for the wet and that for the dry season cultures were prepared as for ordinary corn culture. There were three plowings made at proper intervals, each plowing being followed by harrowing.

The five plots intended for the hand planting method for Native Yellow Flint variety were furrowed, seven furrows being laid for each plot. Planting was done by hand, three to four grains being put in a hill and the seeds covered with soil by the feet. The distance between the hills in the furrows was from 90 to 100 centimeters. The same procedure was followed in the case of Lagkit corn.

No furrows were made in plots intended for the cornplanter method. With the old plate, the cornplanter deposited 5 to 7 grains of the Native Yellow Flint variety in each hill. In the case of Lagkit variety, because of the slightly smaller size of the grains, the number of grains per hill drilled varied from 5 to 10. The distance between hills was from 45 to 60 centimeters.

With the home-made plate, the planter deposited 1 to 3 grains of both varieties in each hill. The distance between hills was from 90 to 100 centimeters.

The same method as described above was used in both the wet and dry season cultures.

RESULTS AND DISCUSSION

Reference to tables 1 and 2 shows that in all instances, with the exception of that with Lagkit variety in the dry season culture, there was a significant increase in the yield of ear corn and volume of grains in favor of the lots planted by machine with the home-made plate.

With regard to weight of stover it was consistently found in the two corn varieties and in both seasons of culture that those lots planted by machine with the old plate produced greater yields. This may be partly explained by the fact that when seeds were planted by machine with the old plate, there was overseeding, 5 to 7 grains of Native Yellow Flint per hill as compared with 1 to 3 sown by hand or by the machine with home-made plate.

In this connection it may be mentioned that in a recent study conducted by Arsenio Juan, 1939,[4] it was found that the yield of pop corn was affected by varying the number of plants in the hill. With 3 used as a standard number of plants per hill, it was found that pop corn gave a yield of 12.45 cavans in the dry season and 14.27 in the wet season. Where the rate of seeding was 4 to 5 plants to the hill, the corresponding yields were 11.95 cavans and 10.96 cavans for the dry season and 12.35 for the wet season. It would seem that the inverse relationship between rate of seeding and yield in pop corn also holds true with ordinary corn as found in this investigation.

Tables 3 and 4 show the computed yields per hectare and cost of production in two seasons of culture. It will be noted that in the case of Native Yellow Flint variety the harvests from those plots planted by machine with the home-made plate were considerably higher than those obtained from the hand planted and those planted by machine with the old plate. These were observed in both wet and dry season cultures. In case of Lagkit variety, however, similar data to those of the Native Yellow Flint were obtained, with the exception that in the dry season the harvest from the corn planted by the machine with the old plate was higher than that from the corn planted by the machine with the home-made plate.

With regard to yield, the order found is as follows:

Machine planted with home-made plate, first; hand planted, second; and machine planted with old plate, third.

With regard to cost of production, the figure obtained from machine planted with the home-made plate was lower than that from the hand planted and from the machine planted with the old plate. This was found true in both seasons. It may also be pointed out that the cost of production for the hand planted was about the same as that for the machine planted with the old plate.

SUMMARY AND CONCLUSIONS

1. The highest yield of corn grains was obtained from the crop planted by the cornplanter with the home-made plate bearing only 5 holes, distanced 6.6 cm. apart and 1.1 cm. in diameter. But the highest yield of stover was obtained from the plot planted by machine with its old plate bearing 12 holes which are spaced 2.8 cm. apart and are 1.9 cm. in diameter.

2. The cheapest method of production of corn grains was obtained with the cornplanter with the home-made plate.

[4] JUAN, ARSENIO G. The effect upon the yield of Pearl pop corn of varying the number of plants in a hill. (Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, 1939. Unpublished.)

TABLE 1

Comparison between hand planted, machine planted (with old plate), machine planted (with new plate), in Native Yellow Flint Corn

Wet season

	MACHINE PLANTED, WITH NEW PLATE	MACHINE PLANTED, WITH OLD PLATE	DIFFERENCE	MACHINE PLANTED, WITH NEW PLATE	HAND PLANTED	DIFFERENCE
Weight of stover (in kilos) ..	167.2 ± 6.79	400.8 ± 14.54	233.6 ± 16.05	167.2 ± 6.79	135.1 ± 8.54	32.1 ± 10.91
Weight of ears (in kilos)	73.7 ± 3.76	28.0 ± 1.59	45.7 ± 4.08	73.7 ± 3.76	59.3 ± 2.31	14.4 ± 4.41
Volume of grains (in gantas) .	23.5 ± 1.40	8.0 ± 0.46	15.5 ± 1.47	23.5 ± 1.40	18.7 ± 0.84	4.8 ± 1.63
Weight of grains (in kilos) ..	52.2 ± 3.16	18.0 ± 1.11	34.2 ± 3.35	52.2 ± 3.16	41.2 ± 1.78	11.0 ± 3.63

Dry season

Weight of stover (in kilos) ..	58.3 ± 2.19	103.7 ± 2.69	45.4 ± 3.47	58.3 ± 2.19	31.1 ± 1.18	27.2 ± 2.49
Weight of ears (in kilos)	82.7 ± 0.82	58.8 ± 1.56	23.9 ± 1.76	82.7 ± 0.82	58.8 ± 0.74	23.9 ± 1.10
Volume of grains (in gantas) .	28.9 ± 0.38	20.9 ± 0.48	8.0 ± 0.61	28.9 ± 0.38	19.6 ± 0.56	9.3 ± 0.68
Weight of grains (in kilos) ..	63.1 ± 0.84	45.5 ± 1.06	17.6 ± 1.35	63.1 ± 0.84	42.8 ± 1.23	20.3 ± 1.49

TABLE 2

Comparison between hand planted, machine planted (with old plate), machine planted (with new plate), in Lagkit Corn

Wet season

	MACHINE PLANTED, WITH NEW PLATE	MACHINE PLANTED, WITH OLD PLATE	DIFFERENCE	MACHINE PLANTED, WITH NEW PLATE	HAND PLANTED	DIFFERENCE
Weight of stover (in kilos) ..	101.5 ± 2.67	377.3 ± 10.45	275.8 ± 10.79	101.5 ± 2.67	85.6 ± 6.14	15.9 ± 6.70
Weight of ears (in kilos)	74.6 ± 3.55	25.0 ± 2.25	49.6 ± 4.20	74.6 ± 3.55	58.4 ± 2.53	16.2 ± 4.36
Volume of grains (in gantas) .	24.7 ± 1.29	7.4 ± 0.68	17.3 ± 1.46	24.7 ± 1.29	18.1 ± 0.88	6.6 ± 1.56
Weight of grains (in kilos) ..	56.7 ± 2.88	17.1 ± 1.58	39.6 ± 3.28	56.7 ± 2.88	41.5 ± 1.92	15.2 ± 3.46

Dry season

Weight of stover (in kilos) ..	10.7 ± 0.49	57.9 ± 2.08	47.2 ± 2.14	10.7 ± 0.49	5.6 ± 0.14	5.1 ± 0.51
Weight of ears (in kilos)	26.1 ± 1.09	68.3 ± 3.36	42.2 ± 3.53	26.1 ± 1.09	15.1 ± 0.19	11.0 ± 1.11
Volume of grains (in gantas) .	9.2 ± 0.39	25.6 ± 0.76	16.4 ± 0.85	9.2 ± 0.39	5.5 ± 0.05	3.7 ± 0.39
Weight of grains (in kilos) ..	20.9 ± 0.90	59.1 ± 1.60	38.2 ± 1.84	20.9 ± 0.90	12.7 ± 0.14	8.2 ± 0.91

TABLE 3

Showing computed total corn production per hectare in cavans

Wet season

AREA	NATIVE YELLOW FLINT			LAGKIT		
	Hand planted	Machine planted, with new plate	Machine planted. with old plate	Hand planted	Machine planted, with new plate	Machine planted, with old plate
	cavans	*cavans*	*cavans*	*cavans*	*cavans*	*cavans*
2,438 sq. m.	3.74	4.71	1.60	3.62	4.95	1.49
1 hectare .	15.34	19.32	6.56	14.85	20.30	6.11

Dry season

1,814 sq. m.	3.93	5.78	4.17	1.10	1.84	5.12
1 hectare .	21.66	31.86	22.99	6.06	10.14	28.22

TABLE 4

Showing total cost of production per hectare

Wet season

AREA	NATIVE YELLOW FLINT			LAGKIT		
	Hand planted	Machine planted, with new plate	Machine planted, with old plate	Hand planted	Machine planted, with new plate	Machine planted. with old plate
	pesos	*pesos*	*pesos*	*pesos*	*pesos*	*pesos*
2,438 sq. m.	14.31	13.38	14.78	14.45	13.52	15.97
1 hectare .	58.70	54.88	60.62	59.27	55.46	65.50

Dry season

1,814 sq. m.	10.31	8.75	10.43	10.43	8.87	11.40
1 hectare .	56.84	48.24	57.50	57.50	48.90	62.84

WILT DISEASE OF ABACÁ, OR MANILA HEMP (MUSA TEXTILIS NÉE)[1]

BERNARDO S. CASTILLO

AND

MARTIN S. CELINO

Of the Department of Plant Pathology

WITH FIVE TEXT FIGURES

According to Leoncio (1930), in 1927, young abacá grown from seeds in Panama and Central America were reported to be infected with a disease similar to banana wilt.[2] In his work to determine whether or not *Fusarium oxysporum* Schlecht. f. 3 Wr. isolated from typical banana-wilt cases could infect young abacá plants, Leoncio (1930) proved conclusively that the fungus could cause abacá wilt. A wilt disease of abacá similar to that described by Leoncio in 1930 was reported by Ocfemia in 1937 as being very serious in Davao, especially at high altitudes. Calinisan (1938a) of the Philippine Bureau of Plant Industry states that the wilt disease of abacá in Davao is associated with a bacterium and a fungus similar to *Fusarium oxysporum* f. 3. The association of a bacterium with abacá wilt is of interest because a wilt of banana, caused by *Bacterium solanacearum* E.F.S., was reported by Ashby in 1926 and 1927 as occurring in Trinidad, British West Indies. Palo and Calinisan (1939), both of the same bureau, worked on the abacá wilt in Davao and stated "...the disease is called 'bacterial wilt of abacá' since the results of the present investigation show that it is due principally to a species of bacteria as will be discussed partly in this report and in succeeding reports." Palo and Calinisan (1939), however admit that "Bacteria and fungi of the genus *Fusarium* were the organisms found commonly associated with the plants affected by the wilt disease. Weevilborers such as *Cosmopolites sordidus* and *Odoiporus paganus* may also be found on plants affected by the wilt disease, but

[1] Experiment Station contribution No. 1360. Prepared in the Department of Plant Pathology under the direction of Associate Professor G. O. Ocfemia.

[2] In the Philippines only the Latundan banana [*Musa sapientum* Linn. var. *cinerea* (Blanco) Teodoro] is susceptible to the wilt disease caused by *Fusarium oxysporum* Schlecht. f. 3 Wr. All of the other varieties of cultivated bananas and plaintains are highly resistant to the disease.

perhaps little importance as contributory factors of the abacá wilt can be ascribed to these insects because a majority of the wilt-infected plants examined did not show them...."

It is evident that two wilt-causing organisms attack abacá in Davao. These organisms can infect abacá independently of each other, and, as Palo and Calinisan (1939) claim, the bacterium is more destructive than the fungus. In the field, however, those abacá plants of which wilting is caused neither by the bacterium nor the fungus alone but by the combined action of the two organisms are hard to separate. In the present paper the writers report the identity and the pathogenicity of the fungus associated with the abacá wilt collected in Davao in 1937.

THE DISEASE

History, distribution, and economic importance

Palo and Calinisan (1939) give the history, distribution, economic importance, and relation to abacá varieties of the bacterial wilt disease in Davao. These authors consider the bacterial wilt "...the most serious of all the abacá maladies found in Davao, Mindanao." In a survey to determine the economic importance of the wilt disease, all of the cases caused by *Fusarium oxysporum* f. 3 can not be excluded from consideration. In 1937, Ocfemia noted that the banana-wilt-like disease is very destructive to old abacá plants in the plantations of the Mindanao Reclamation Company at Tunkalan at an elevation of 500 meters (1640 feet) above sea level.

Symptoms

Early stage of infection. On abacá seedlings the first noticeable symptoms of the disease are the inward curling of the leaf blades at or near the tip of the lower leaves and the slow growth of the plants. After about a month the lower leaves show a loss of turgidity and gradually droop or wilt. The wilting of the leaves begin at the tip, and soon the blades turn from yellowish to yellowish brown.

Advanced stage of infection. As infection advances, more of the lower leaves wilt. New leaves appear, but they are reduced in size and also wilt and dry. No conspicuous bunching of the petioles at the upper end of the pseudo-stem and splitting of the pseudo-stem from the base upwards, which is characteristic of the wilt of Latundan banana [*Musa sapientum* Linn. var. *cinerea* (Blanco) Teodoro], may be noted. When corms of wilted abacá plants are cut open, the reddish violet color of the vascular bundles is evident. In more advanced

cases the roots and the corms of infected plants gradually rot. The rotting of the corm is more rapid when it is infested with the root weevil (*Cosmopolites sordidus* Germar).

Latundan banana suckers inoculated with pure cultures of the abacá-wilt fungus showed a stunted growth of the stalk and conspicuous wilted condition of the lower leaves (fig. 1). The upper leaves showed a tendency to bunch. The pseudo-stem split at the base, and sometimes the splitting extended upward to the base of the petioles

Fig. 1.—Latundan banana suckers with fresh wounds on the corms: the sucker to the left was planted in a soil heavily infested with pure cultures of the *Fusarium oxysporum* isolated from abacá wilt disease. Note the wilting leaves of the plant to the left and the vigorous appearance of the sucker to the right which was planted in sterilized soil as control. Photograph by the Photographic Division, College of Agriculture.

of the old leaves. The reddish violet color of the vascular bundles was similarly pronounced in the corms and in the leaf sheaths. As a final stage of the disease, the roots and the corms rotted, and the entire plants died. The symptoms and effects produced on the Latundan banana by the fungus isolated from abacá were the same as those caused by the banana strain of *Fusarium oxysporum* f. 3.

CAUSAL ORGANISM

The fungus associated with abacá wilt was isolated to pure cultuer from corms of infected plants brought by G. O. Ocfemia from Davao during his trip in May, 1937.

Morphological characters

Mycelium. In young cultures, the mycelium of the abacá-wilt fungus is a white cottony mass on the surface of the media. In old cultures, the hyphae are less granular than in young, and in many instances they are vacuolate. The hyphae are fine, branched, hyaline, straight, and constricted at the septa. The cells range from 3.4 to 13.6 μ in length and 3.4 μ in width; the average is 8.48 by 3.4μ.

Conidiophores. The conidiophores (fig. 2, a) are borne laterally on the aerial mycelium. They are hyaline, septate, and either simple or branched. The simple conidiophores gradually taper at the ends, are constricted at the point of origin and at the septa, and are slightly bulged in the middle. The branches of the conidiophores are arranged in whorls of three or more. On potato-dextrose agar they begin to form in ten to fourteen hours. The main axis of the conidiophores are 57.8 to 73.1 by 3.4 to 5.1 μ; the average is 67.7 by 3.4 μ. The lateral branches vary from 6.8 to 13.6 μ long.

Microconidia. The microconidia (fig. 2, b) are hyaline, ovoid to elongate, usually numerous, either one-celled or two-celled, mostly 0-septate, and 5.7 to 15.2 by 3.4 to 3.8 μ; the average is 8.8 by 3.4 μ.

Macroconidia. The macroconidia (fig. 2, c) are hyaline, sickle-shaped, majority 3- to 5-septate with the 3-septate predominating. The macroconidia are 23.8 to 42.0 by 3.8 to 5.1 μ; the average is 30.5 by 4.0 μ. In the abacá-wilt *Fusarium,* the macroconidia differ slightly from those reported by other workers. These differences, however, probably due chiefly to climatic conditions, are not sufficient to make the writers' abacá-wilt *Fusarium* a different species from *F. oxysporum* f. 3. The length of the 3-septate conidia are within the range given by Wollenweber and Reinking (1927) for this type of spore. The writers' figure for the 3-septate conidia are very close to those of Erwin F. Smith (1910) in his original description of *F. cubense* on banana and of Wollenweber and Reinking for *F. oxysporum* f. 3. Wr. also on banana.

Chlamydospores. The chlamydospores are either conidial or intercalary. They are produced abundantly in cultures three to four weeks old. The intercalary chlamydospores (fig. 2, d) are more or less spherical, in chains, and vary in diameter from 3.8 to 5.7 μ. The conidial chlamydospores (fig. 2, e) are more elongate than

spherical, deeper in color than those of the mycelium, and have a pellucid ring within the sclerotia. They measure from 5.7 to 7.6 by 3.8 to 5.7 μ. The average is 6.82 by 4.26 μ.

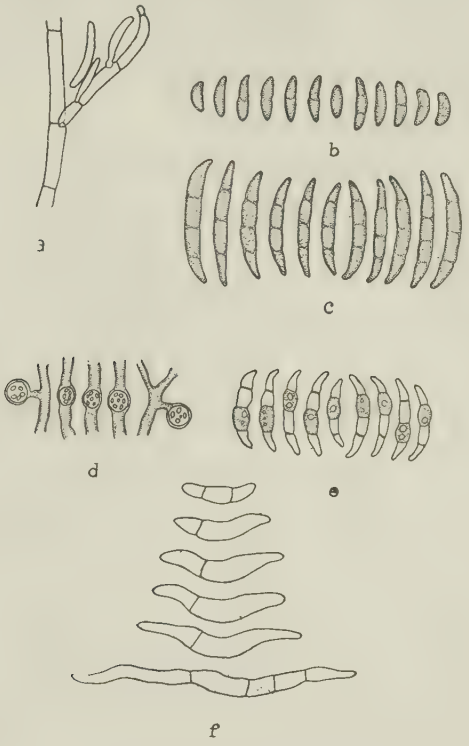

Fig. 2.—Camera lucida drawings by the senior writer showing: (*a*) portion of the mycelium and conidiophores of *Fusarium oxysporum* Schlecht. f. 3 Wr. of the abacá wilt with a few scattered microconidia as seen from a hanging drop preparation over a hollow ground slide, (*b*) microconidia from a 28-day old culture on potato-dextrose agar, (*c*) macroconidia from a 28-day old culture on potato-dextrose agar, (*d*) hyphal chlamydospores from a 60-day old culture on banana fruit plug, (*e*) conidial chlamydospores from a 60-day old culture on banana fruit plug, and (*f*) germinating macroconidia. All drawings × 1063.

In pure culture, the formaldehyde and benzoic-acid like odor described by Brandes (1919) as emitted by *Fusarium oxysporum* Schlecht. f. 3 of the banana wilt was also noted by the writers.

From the morphological stand point, the macroconidia of the writers' abacá-wilt *Fusarium* is a little longer and broader than those of *Fusarium oxysporum*. The slight difference in size, however, is not considered sufficient to segregate from *F. oxysporum* the writers' abacá-wilt fungus. The writers conclude, therefore, that the abacá-wilt *Fusarium* is identical morphologically with the *Fusarium oxysporum* Schlecht. f. 3 of Wollenweber.

Germination of conidia

The conidia were germinated on thin layers of potato-dextrose agar on sterile cover glasses. The cover slips were placed on hollow ground slides and kept in a moist chamber. The conidia germinated in five to seven hours (fig. 2, f). Each conidium produced from one to two germ tubes. In about twenty-four hours, a thin mat of hyphal threads was evident. At about this time conidiophores began to appear and subsequently the conidia were formed.

Physiology: Cultural studies

The abacá-wilt fungus was grown on different culture media, and the results obtained in this study may be briefly summarized as follows:

Oatmeal agar. The fungous growth was at first submerged. One to two days later, white cottony aërial hyphae began to appear on the surface. After a week the surface of the slant was practically covered with white vinaceous-gray [3] mycelium. The aërial growth was thicker at the base than at any other place on the agar. The media produced cinnamon-buff microconidia and macroconidia. They were produced in abundance within twenty-four hours.

Potato-dextrose agar. The growth of the mycelium was at first submerged with a little aërial development. Later on, white to light-ochraceous-buff mycelium appeared profusely. With age the growth became pale pink. The substratum became dark slate-violet. After five days the entire media was covered with aërial hyphae. Both microconidia and macroconidia were in abundance.

Steamed rice. A mass of white mycelium was produced luxuriantly. The substratum became pink, and with age it turned purple or blue. A detectable formaldehyde and benzoic-like odor was produced. The macroconidia were noticeably fewer in number than the microconidia.

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[3] Ridgway, R. 1912. Color standards and color nomenclature. 43 pp., *53 col. pl.; 1115 named colors.* Washington, D. C.

Abacá corm plug. The growth of the fungus was profuse. The mycelium was white to dusky brown. The macroconidia were relatively fewer than the microconidia.

Potato plug. The mycelium was white to violet and abundant on the surface. The entire surface of substrate was covered with fungous growth in three days. Old cultures changed from slate violet to vinaceous purple. Microconidia and macroconidia were produced in twenty-four hours. Unlike in the other media and substrates, the fungus produced more macroconidia than microconidia on potato plug.

Banana corm plug. The foungus growth was submerged and cobwebby. After four days, the entire surface of the substrate was practically covered with the aërial mycelium. The mycelium was white to dark purple-drab. Both macroconidia and microconidia were produced within twenty-four hours; the former were relatively more than the latter.

Bean plug. The fungus grew profusely on this substrate. A thick aërial mat of mycelium covered the surface of the substrate within twenty-four hours. The microconidia were relatively more than the macroconidia.

In the cultural studies the writers noted that the abacá-wilt fungus produced a comparatively good growth on potato plug, abacá and banana corm plugs, camote plug, bean pod, cabbage petiole, potato-dextrose agar, steamed rice, oatmeal agar, and banana fruit plug. The fungus produced a poor growth on water agar and on abacá and banana petioles. On the whole the cultural features of the fungus on agar media where dextrose was added and on sterilized plant tissues did not vary much. Mycelium and spores were produced in abundance. The cottony white hyphal growths on culture media were evident during the first two days. The growth changed with age from white to violet, vinaceous, or lilac.

Proof of pathogenicity

Inoculation experiments were conducted with the *Fusarium* isolated from abacá corms infected with wilt disease. Abacá seedlings grown from seeds and healthy Latundan banana all planted in sterilized soil were used.

Abacá seedlings. The abacá seedlings were raised from seeds obtained from Davao, Davao and from Paete, Laguna. The seeds were sterilized by immersion in 1:1000 mercuric bichloride solution, washed with several changes of sterile water, and then germinated in sterilized soil in pots. As soon as the seedlings produced from

four to five leaves, they were transplanted in sterile soil in pots, at the rate of one seedling to a pot. When the potted plants were about four to twelve months old, the seedlings were used in inoculation experiments.

Latundan banana suckers. Healthy suckers of Latundan banana were obtained from a field in Los Baños, Laguna where the banana-wilt disease had never been observed. The corms of these suckers were removed and thoroughly washed with water, cut to convenient sizes, sterilized by immersion in 1:1000 mercuric bichloride solution, and then thoroughly washed with sterile water. The sections of the corms were planted in sterilized soil in pots and in kerosene cans.

The soil used. The soil used in all of the experiments was clay loam collected from the U. P. Rural High School garden. It was mixed thoroughly and passed through a sieve to eliminate the coarse materials. The sifted soil was sterilized by direct heating on a galvanized iron pan for abcut one hour. While being heated, the soil was frequently stirred in order to prevent burning the organic matter.

Methods of inoculation. The abacá seedlings and the young sprouts of Latundan banana were removed from the pots where they were originally grown. Care was taken not to injure their roots and corms, which were later washed by faucet water. In the first series of soil inoculation experiments after washing, the seedlings were planted in previously sterilized soil to which had been mixed pure cultures of the abacá-wilt *Fusarium* grown on steamed corn meal. In the second series some of the roots of the abacá seedlings were cut off and a portion of their corms shaved before they were planted in the inoculated soil. In the third series the spores and mycelium of the fungus were smeared on the surface of the fresh wounds on the corms before they were planted in sterilized soil in pots. After planting, the soil was watered, and the pots were kept in the shade for about one week in order to allow the plants to become established. After one week in the shade, the pots were placed outside the laboratory, but under partial shade, for observation. The control seedlings were similarly treated, except that no fungus was added.

The effect of the fungus upon uninjured abacá seedlings

Experiment 1. On February 16, 1938, fourteen abacá seedlings, seven to eight months old, were used in soil inoculation as above described, and fourteen plants were used as checks.

After two weeks the experimental and check abacá plants had recovered from the effect of transplanting.

At the end of thirty days, two of the inoculated plants showed a slight wilting of the lower leaves, and five days later, three more plants showed similar symptoms. In no instance did infection occur on any of the plants in the control. Further observations showed that of the five plants infected with the disease, two died after three months. The other three gradually recovered and outgrew the disease. When the roots and the corms of the dead plants were examined, they showed rot of varying degrees of severity and reddened bundles in the vascular region. In addition the corms were partly damaged by root weevil, *Cosmopolites sordidus* Germar, and were badly invaded by nematodes and bacteria. In this experiment the death of the plants was believed to be partly due to the destruction of the corm by weevil. The nematodes and bacteria were probably already in the roots of the seedlings used, but they increased in number and their injury became evident only when the seedlings were weakened by the fungus and insect attack. Isolations made from the diseased corms yielded a species of *Fusarium* similar to the original isolations.

Experiment 2. Twenty-four 4 month old abacá seedlings were inoculated and fourteen of them or 58.33 per cent wilted. These wilted plants died after thirty days. The other ten showed a slightly wilted condition of the leaves and were noticeably stunted in growth for some time. They recovered, however, after twelve months and grew normally with no symptom of infection. All the fourteen check plants remained healthy during the entire period of the experiment.

The results of the two experiments showed that the *Fusarium* isolated from wilted abacá plants is capable of infecting young abacá seedlings. In Experiment 1, in which the abacá seedlings were seven to eight months old, the percentage of infection was lower than that in Experiment 2. In Experiment 2, in which four months old abacá seedlings were used, a 58.33 per cent infection was obtained, and all the infected seedlings died. The death of the seedlings in Experiment 2 was attributed to the fungus alone because no insects were associated with the rotted roots and corms. Instead, fungus mycelium and spores of *Fusarium* were found associated with the roots and corms of the dead plants. In Experiment 1, where seven to eight month old seedlings were used, only a 35.71 per cent infection was obtained. The mortality was, however, only 14.29 per cent. In addition to the fact that the degree of infection decreased as older abacá seedlings were used, the writers noted that when older seedlings

were inoculated, many of the fast growing plants recovered from the wilt and eventually outgrew the disease. These results are in accord with observations reported by Leoncio (1930) and J. H. Permar of the United Fruit Company in the Republic of Panama.

The apparent severity of the disease on young seedlings may perhaps be attributed to the fact that both the corms and the roots of young plants are more or less tender and, therefore, easier to penetrate by the fungus than those of older plants.

Experiment 3. On July 22, eleven healthy Latundan banana suckers 30 to 60 centimeters tall were inoculated, and an equal number of healthy suckers were used as control. In the Latundan banana wounds could not be avoided in the separation of the suckers from the mother corm. By the time they were used in inoculation experiment, however, the wounded surface had already developed a protective covering so that the wound was no longer fresh.

On December 1, 1938, two of the inoculated plants wilted. Five others showed symptoms of the disease on January 12, 23, and 27, 1939. These infected plants produced short narrow leaves and remained conspicuously stunted in growth. The characteristic splitting or cracking of the pseudo-stems was observed on four of the infected plants. When the plants were dug up after eight months, the interior region of the corms (fig. 3) showed the reddish-violet color similar to that noted in the corms of the inoculated abacá plants. In addition the infection was observed to have spread to the corms of the young sucker buds. This method of spread of the disease in the corms of Latundan banana was not observed on the young infected abacá seedlings, although larger and older abacá plants commonly show it in the field. In Experiment 1 and 2, the suckers of the fast growing plants of some of the artificially infected abacá did not become infected from the corms of the mother plants. It may also be mentioned in this connection that when the abacá-wilt infected abacá corms from Davao were planted in sterilized soil in cans, they produced suckers that did not show the disease. In some instances, however, the spread of the disease from old infected corms to their suckers was facilitated by weevils that had gained entrance into these organs.

The effect of the fungus upon abacá seedlings and Latundan banana suckers with injured corms and roots

In these experiments some of the roots were cut off and a portion of the corm shaved before the seedlings were planted in soil pre-

viously infected with pure cultures of the *Fusarium* isolated from field cases of abacá wilt.

Experiment 1. On March 17, 1938, twenty-eight one year old abacá seedlings were used in this experiment; fourteen for inoculation and fourteen for control. On April 12, two of the plants in the inoculated pots showed symptoms of the wilt disease. Two days later, the remaining twelve plants exhibited similar symptoms. In

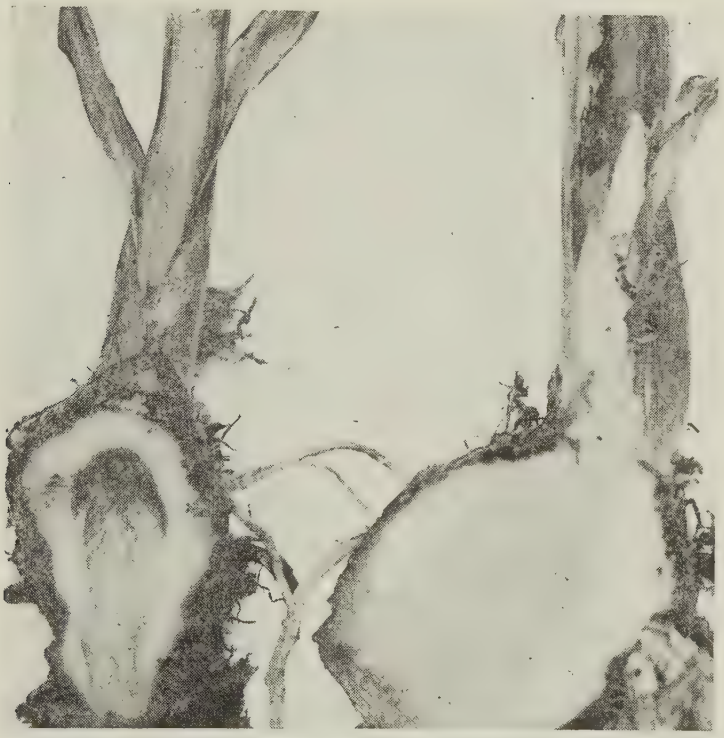

Fig. 3.—Longitudinal sections of the corms of Latundan banana showing the effect of the fungus on the tissues. The plant to the right is the control, and the sucker to the left the inoculated. Note the dark colored area in the corm of the sucker inoculated with *Fusarium oxysporum* f. 3 from abacá wilt. Photograph by the Photographic Division, College of Agriculture.

the early stage of the disease, only one or two of the lower leaves of the infected plants showed a slight loss of turgescence and drooped. As the disease progressed, more leaves became involved. The wilted leaves gradually changed from green to yellowish or pale yellow

Fig. 4.—The abacá seedling to the right was planted in a soil heavily infested with *Fusarium oxysporum* Schlecht. f. 3 Wr. at the age of one year. Its corm was injured by shaving a portion from it before it was planted. The plant to the left is the control. Photograph by the Photographic Division, College of Agriculture.

(fig. 4). The cracking or splitting of the pseudo-stem, similar to that produced by *Fusarium oxysporum* f. 3 on Latundan banana, was not observed on the artificially infected abacá plants. In the ad-

vanced stage of the disease, nine of the fourteen experimental plants, or 64.29 per cent, died. When the corms of these dead plants were examined, they showed, in addition to fungous attack, injuries that were caused by insects. In two or three instances grubs and adult weevil, *Cosmopolites sordidus* Germar, were found in the corms. Evidently, the insect not only produced additional openings in the corms for the entrance of fungous parasite, but it weakened the host considerably and finally killed the seedlings. The other five infected

Fig. 5.—A photograph showing an infected abacá seedling to the right recovering from the wilt disease. Note that the curling of the lamina inward is still shown by the third leaf, but the younger leaves are fully expanded. Note also the vigorous appearance of the control seedling to the left. Photograph by the Photographic Division, College of Agriculture.

abacá plants continued to grow with a slight indication of wilt and remained more or less stunted in growth for about five months. After eight months these infected plants grew faster and developed leaves with inconspicuous symptoms of the disease (fig. 5). A further increase in the rate of growth of the seedlings resulted in the complete disappearance of the symptoms on the leaves after a period of one year. Two of these plants that had apparently recovered were dug up, and the roots and the corms were dissected for a more detailed examination. The mycelium of the fungus and in a few in-

stances the conidia of the *Fusarium* used were still associated with certain portions of the old roots and the outer dead portions of the corms. When the interior regions of the corms were examined, they were found free from any trace of fungous attack. Of the check plants, three wilted and finally died as a result of invasion by root weevils. The corms were either partly eaten at various places, or tunnels were made by the insect through them. No fungous attack, however, was noted in any of the three cases.

Experiment 2. On May 20, 1939, fourteen one year old abacá seedlings were used in inoculation and seven seedlings were used as checks. Four months after inoculation, 11 or 78.57 per cent of the seedlings became infected. In the early stage of the disease only the first two to three mature lower leaves of the plants drooped downward and appeared slightly wilted. The wilting symptom did not appear on subsequent leaves. The infected plants, however, became stunted in growth. They produced short, narrow leaves that had a tendency to bunch on the upper portion of the pseudo-stem. On account of the limited amount of soil in the culture cans, equal amounts of sterilized compost were added to each of the cultures of both the inoculated and the control plots. All of the plants excepting three of the inoculated responded to the treatment and improved considerably in growth. When these three diseased looking plants were dug up and examined, they showed brown to reddish violet vessels in different parts of the vascular regions. The infection seemed to be confined to the portion of the mother corm to which the suckers were attached. The corms of the young suckers produced by one of the infected corms did not show the characteristic discoloration of the vascular bundles at the time of the examination.

Experiment 3. On November 30, 1938, sixteen Latundan banana suckers were used in soil inoculation, and an equal number were used as control.

In this experiment, some of the inoculated plants showed infection after sixty days. Two plants started to wilt on January 5, 1939, one on January 16, four on February 3, two on March 2, and three on March 20, 1939. After six months the infected plants were conspicuously stunted in growth, and some of them showed the bunchy arrangement of the leaves on the upper portions of the pseudo-stems. Longitudinal splitting of the stem was produced, and in some instances it extended from the base of the stalk to the bases of the petioles of the leaves. Suckers were produced, but in the majority of cases, these became infected and failed to grow normally. Owing

perhaps to the fact that the corms of the experimental plants were injured when they were separated from the mother plants, infection appeared much earlier in these plants than it did on the plants in Experiment 3 of the series where the roots and corms did not have fresh wounds. Furthermore, a slightly higher percentage of infection was obtained in this experiment than in Experiment 3 of the first series.

The effect of the fungus smeared upon the injured corms of abacá suckers

In this series of inoculation, fungous spores together with the mycelium were smeared on the surface of the fresh wounds. On the control seedlings, sterile potato-dextrose agar was used instead of fungous spores and mycelium.

Experiment 1. On July 4, 1938, sixteen one year old abacá seedlings were inoculated as described above, and eight were used as control. After four months, seven of the seedlings in the inoculated lot showed stunted growth and a slight wilting of the leaves. Three months after the appearance of the disease on seven plants, two other seedlings exhibited similar symptoms. Likewise, four of the check plants wilted and subsequently died. When the wilted plants in both experimental and check lots were dug up and examined, only two of those in the inoculated lot showed unmistakable symptoms of *Fusarium* infection in the corm. The corms of the other plants were badly infested with weevils, which had bored into the corms until, in some cases, the tunnel extended to and destroyed the growing points of the plants. The destruction of the corms and infestation of the growing point apparently caused the death of these plants.

In their inoculation experiments with the *Bacterium* which they claim to be the chief cause of abacá wilt in Davao, Palo and Calinisan (1939) found that many of their abacá plants were not infected, some became readily infected, others showed infection but the disease did not progress, and still others showed infection only after a prolonged incubation period.

In the writers' inoculation experiments, although the fungus was capable of infecting young abacá seedlings and suckers of Latundan banana, it was not able to infect the uninjured corms of one year old abacá seedlings with the same degree of severity as it did the younger ones. The results also showed that the fungous invasion appeared to be more severe on abacá and banana plants of which the corms were infested by the corm weevil. This is perhaps due to the

fact that the injuries caused by the insect not only provided openings for the entrance of the fungous invader, but also the insects themselves seriously injured the plants. While it can not be doubted that the fungus *Fusarium* of the abacá wilt can infect abacá and banana independently of the corm weevil, it is apparent that the severity of the disease was caused in a large measure by the joint action of the fungous parasite and the insect pest. Although these results were obtained under conditions existing in pot cultures, there is little doubt that a parallel situation also exists in the field. Ocfemia (1937) believes that the destructiveness of the wilt disease of abacá on the higher altitude in Davao is due to the combined attack of *Fusarium oxysporum* and the abacá weevil, *Odoiporus* sp., in a situation unfavorable for the growth of abacá.

Taxonomy

Morphological and physiological studies and inoculation experiments showed that the abacá wilt fungus has many points of similarity to the banana-wilt fungus, *Fusarium oxysporum* Schlecht. f. 3 Wr. (= *F. cubense* E.F.S.). The abacá-wilt *Fusarium* belongs to the Section Elegans of Wollenweber, Sherbakoff, Reinking, Johann, and Bailey (1925). The 0-septate conidia are not in chains. The conidial walls are thin; the macroconidia attenuate at the top ends, and are pedicellate. The color of the substratum is principally vinaceous to lilac.

The size of the 3-septate conidia [4] resembles closely that of *F. oxysporum* Schlecht. f. 3 Wr. (= *F. cubense* E.F.S.). The description of the fungus under study agrees closely with that of the other investigators, although it differs slightly in the size of the 3-septate conidia.

According to Reinking and Wollenweber (1927), the 3-septate conidia of *F. cubense* E.F.S. obtained from potato-agar culture is 23 to 44 by 3.5 to 4.5 μ (average 32 by 4.0 μ), and those for *F. oxysporum* Schlecht. f. 3 Wr. are 23 to 32 by 3.5 to 4.0 μ (average 28 by 3.75 μ). The abacá wilt *Fusarium* also obtained from potato agar culture is 19 to 41.8 by 3.8 to 4.0 μ (average 29.6 by 4.0 μ). As may be noted from the figures, the writers' fungus differs slightly from those of Reinking and Wollenweber (1927) because it is a little

[4] The type of conidia previously used by the writers in comparing the abacá wilt *Fusarium* with the findings of the different investigators is the 3-septate conidia as they form the normal spore. According to Wollenweber, H. W., C. D., Sherbakoff, A. O., Reinking, Helen Johann, and Alice Bailey (1923), the normal macroconidia form the basis for a natural classification.

shorter, although a little longer and broader, than those of Erwin F. Smith's *Fusarium cubense*. The fungus studied by the writers compared so closely with *Fusarium oxysporum* f. 3 that the abacá-wilt fungus can not be considered a different species. The slight discrepancy in size may perhaps be attributed to the technic followed in growing the fungus, to difference of hosts or locations in which the fungus was isolated, and to climatic conditions. It is thus concluded that the cause of the abacá-wilt in the Philippines is *Fusarium oxysporum* Schlecht. f. 3 Wr. (= *F. cubense* E.F.S.).

Reinking (1934) reports that the symptomatic and isolation studies clearly show that the banana wilt (Panama disease) is identical in the following countries: Philippine Islands, Straits Settlements (Singapore, Penang), Federated Malay States, Siam, Dutch East Indies, Australia, Burma, and India. The wilt causing fungus of abacá and banana is thus widely distributed. The only reason the disease caused by the fungus is not as wide spread as the distribution is that in most places the conditions are favorable for the growth of the host. The disease is severe in abacá plantations where conditions are not good for the growth of abacá.

It seems probable that abacá is infected with the wilt fungus from Latundan banana or from the organisms in the soil that came from the banana. The spread of the disease in abacá plantation is probably due to the use of wilt-infected abacá suckers in an effort to extend the area of abacá plantations.

THE FACTORS THAT FAVORS SEVERITY OF ABACÁ WILT

In the inoculation experiments, infection with the wilt disease caused by *Fusarium oxysporum* f. 3 was aggravated by the attack of the corm weevil, *Cosmopolites sordidus*. It attacked the corms and often extended its tunnels to the central cylinder, where the growing points of the abacá is situated.

The banana-wilt-like disease of abacá in Davao was prevalent in older plants where the stem-weevil, *Odoiporus* sp., is a destructive pest. The disease appears very destructive at higher elevations especially where the surface soil and organic matter had been washed away.

HOW THE ABACÁ WILT FUNGUS MAY BE SPREAD

The dissemination of the abacá-wilt fungus may be accomplished by planting diseased suckers and corms. Microscopical examination of sections made from the violet colored streaks of the vascular vessels showed mycelium in the parenchyma cells and in the xylem vessels.

Ocfemia (1937) reports that in the Pendisaan Plantation, Inc., the replants used were large abacá corms; the tops had been cut off and some of the corms were either halved or not cut. If these planting materials are infected and shipped to other places, they will disseminate the disease, leaving the fungus in the soil to become soil-borne.

Examinations of the leaf-bases and leaf-stalks of rotting plants made by the writers revealed an abundance of spores of *Fusarium oxysporum* f. 3. The presence of the fungus on these parts of abacá is of importance because the leaf sheaths are often used for tying planting materials to be transported to other regions.

According to Hansford (1923), Prescott in 1917 isolated a number of *Fusaria* from soils which the latter called "healthy" and "diseased." These *Fusaria* were said to correspond very closely in cultures to *Fusarium oxysporum* f. 3. Prescott concluded that the spores may be present in "healthy" soil.

It seems evident that any soil from infected areas is liable to carry *Fusarium oxysporum* f. 3 with it.

The spores in the soil and in debris may also be spread by water when it rains. The soil that adheres to the feet of man and animals and to tools and roots of abacá and other crops may be a means of spreading the abacá and banana wilt fungus to other places.

CONTROL MEASURES

From what is known about the abacá wilt disease and its cause, the writers believe that the control measures should not differ from those used with the banana-wilt disease.

The writers did not conduct experiments for the control of abacá wilt in Davao. From their study of the abacá-wilt disease and its cause and from literature on banana wilt, the writers believe that the following suggestions should prove to be of value in abacá plantations.

Exclusionary measures

In regions where the wilt disease of abacá caused by *Fusarium oxysporum* f. 3 is not known to occur, it is very important that the planters should examine all abacá and banana suckers or corms for planting purposes. The corms of the suckers should be examined carefully after they have been severed from the mother corms, so that if any of the violet colored streaks are shown on the cut surface, the suckers should be discarded and not used for planting.

Although the disease caused by *Fusarium oxysporum* f. 3 is the least destructive of the three major maladies of abacá in Davao, the wilt is the most difficult to control, because its causal organism is a facultative saprophyte, and once the fungus is in the soil, it will remain in that soil indefinitely.

Sanitary measures

Should abacá wilt caused by *Fusarium oxysporum* f. 3 occur in a sporadic form, the plantation should be inspected carefully and regularly. Abacá plants found to be infected with the disease should be cut down, and all the roots and corms should be dug up. These should be chopped into thin slices where they have been dug up, piled in heaps on top of dry wood, bamboo, and rubbish, and finally burned to ashes. Every plant within a radius of ten meters from an infected plant should be dug up and the corm examined for the presence of the reddish violet color. No abacá or plants belonging to the genus *Musa* should be planted in the cleaned areas.

In order to prevent the disease from spreading, the hands and shoes of laborers and the tools used in working in an abacá field should be disinfected with mercuric bichloride solution (1:1000) before a field is left where the abacá wilt occurs.

For the abacá wilt in Davao, Ocfemia (1937) recommends the complete destruction of severely infected plantations, because they are not suitable for abacá He suggests that the land be planted to crops recommended for Davao conditions by the Bago Experimental Station.

SUMMARY

1. A study was made of the abacá-wilt disease to determine whether or not its causal agent is identical with the fungus responsible for the banana-wilt disease.

2. The fungus used in the experiments was isolated from abacá plants infected with abacá wilt and brought to Los Baños from Davao.

3. The symptoms produced on inoculated abacá seedlings are inward curling of the leaf blades at or near the tip of the lower leaves, bunching of the leaves, slow growth of the plant, and the violet color of the vascular bundles. No cracking of the pseudo-stem of abacá similar to that shown by Latundan banana was observed.

4. Infection of abacá seedlings and Latundan banana suckers was obtained in artificial inoculations with pure cultures of the fungus, either by applying it directly on the corms or by mixing pure cultures of the fungus with sterilized soil.

5. The fungus infected young abacá seedlings whether or not they had fresh injuries on the roots and corms. With four month old abacá seedlings, a 58.33 per cent infection was obtained, and all the infected plants died. With one year old seedlings, 35.71 per cent showed infection, but only 14.28 per cent died. The symptoms of infection in artificial inoculations were noticeable in one to four months after inoculations.

6. The severity of the abacá wilt disease in the experimental plants was aggravated by injuries caused by the corm weevil *Cosmopolites sordidus* Germar.

7. The abacá-wilt fungus infected Latundan suckers whether or not these had fresh injuries on the corm and roots. The fungus produced visible symptoms in from two to six months.

8. Morphological and cultural studies and inoculation experiments show that the fungus associated with abacá wilt is identical with *Fusarium oxysporum* Schlecht. f. 3 Wr. (= *F. cubense* E.F.S.) that causes banana wilt.

9. For the control of abacá wilt, introduction and establishment of the parasite in regions where it does not occur should be prevented. A complete eradication of all diseased plants is important in new outbreaks.

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Ocfemia, G. O. 1937. The abacá-disease situation in Davao. The Philippine Agriculturist **26**: 229–236. *Fig. 1–2.*

PALO, MACARIO A., AND MELANIO R. CALINISAN. 1939. The bacterial wilt of the abacá (Manila hemp) plant in Davao: I. Nature of the disease and pathogenicity tests. Philippine Jour. Agric. **10**: 373–395. *Pl. 1–15.*

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COLLEGE AND ALUMNI NOTES

The officers of the Society for the Advancement of Research (SAR) for the current term, 1940-1941, are: L. G. Gonzalez, President; A. P. Racelis, Vice-President; F. M. Salvoza, Secretary; S. M. Cendaña, Treasurer.

The Los Baños Biological Club has the following officers: Dr. F. M. Salvoza, president, and Dr. S. M. Cendaña, secretary.

The following students of the College were awarded degrees at the thirtieth annual commencement exercises of the University of the Philippines on April 2, 1940:

Bachelor of Science in Agriculture

1. Manuel C. Agda
2. Eugenio A. Alcasid (Baker Scholar)
3. Cesareo E. Alviar
4. Pedro S. Asuncion
5. Calixto P. Baladad
6. Rafael O. Bartolome
7. Felipe T. Benabaye
8. Aniceto C. Bueno
9. Jose G. Cadiz
10. Bernardo S. Castillo
11. Nicolas G. Dabu
12. Daniel F. Francisco
13. Ernesto P. Gabriel
14. Emmanuel T. Gervacio
15. Pedro E. Gloria
16. Fidela L. Ilag
17. Cenon P. Ilao
18. Juan I. Ilustre
19. Martin V. Jarmin
20. Eduardo C. Lecciones
21. Jose M. Madrigal, Jr.
22. Florendo R. Naanep
23. Elias C. Neypes
24. Basilio O. Nuevo
25. Sixto C. Orig
26. Maximo R. Pegenia
27. Amante E. Pinpin
28. Potenciano C. Reaño
29. Ramon D. Rojas
30. Francisco F. Saguiguit
31. Olegario M. Sasis
32. Francisco R. Soriano
33. Jose R. Velasco (Cum laude)
34. Yang Yong Vimuktanandana
35. Davi Yanasugondha
36. Pedro J. Zuñiga

Bachelor of Science in Sugar Technology

1. Marcelo R. Caguioa

Certificate in Agricultural Education

1. Calixto P. Baladad
2. Francisco F. Saguiguit

Associate in Agriculture

1. Mohammad Ali Hanafiah Loebis

For being the first alumnus to become President of the University, Dr. Bienvenido M. Gonzalez was honored on March 31 by the unveiling of a commemorative plaque in the East Corridor of the Rafael Palma Hall.

President Gonzalez was also awarded during the commencement exercises on April 2 a gold medal as one of this year's most distinguished alumni of the University.

THE EXPERIMENT STATION

LIST OF AVAILABLE CIRCULARS

Circular No. 2.—Bud Rot of Coconut (Revised. June, 1934) - - - *By G. O. Ocfemia*

Circular No. 3.—Experimental Errors and Application of the Probable Error to and the Interpretation of Experimental Results - - - - - - - - - - - - - *By Nemesio B. Mendiola* (Published as Chapter IV in *A Manual of Plant Breeding for the Tropics*, 1926, also sold by THE PHILIPPINE AGRICULTURIST at ₱3.25, paper bound, and ₱5.25, cloth bound, in the Philippines, and ₱3.50 and ₱5.50 elsewhere, postpaid.)

Circular No. 5.—Poultry Raising Made Easy (Revised) - - - - *By F. M. Fronda*

Circular No. 7.—How to Produce New Varieties of Gumamela (Hibiscus) - - - - - - - - - - - - *By Nemesio B. Mendiola*

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